RADIUM CITY

A HISTORY OF AMERICA'S FIRST NUCLEAR INDUSTRY

JOEL O. LUBENAU

&

EDWARD R. LANDA

We are in the habit of speaking of Pittsburgh as "The Iron City." We sometimes call it "The Steel City." It may also justly called "The Radium City."

William J. Holland, Director, Carnegie Institute, Pittsburgh. From Dr. Holland's remarks at the May 26, 1921 University of Pittsburgh Convocation to confer an Honorary Degree of Doctor of Laws on Marie Curie.

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BY

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PPG	Pittsburgh Post-Gazette.
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UP2	University of Pittsburgh School of Medicine.
USCS	U.S. Congress. Senate. Committee on Mines and Mining. *Radium: Hearing before the Committee on Mines and Mining on S. 4405*, 63rd Cong., 2nd sess., February 10-24, 1914.
USDOE	U.S. Department of Energy, DOE/EM-0319
WPI	Wark Photography, Inc., Pueblo, CO.

FOREWORD

J. Samuel Walker

In *Radium City*, Joel Lubenau and Edward Landa trace two prominent and intersecting themes. The first is a little-known but important chapter in the local history of Pittsburgh and the surrounding region of southwestern Pennsylvania. The other is the history of the early radium industry in the United States. The production and sale of radium began with wildly inflated hopes about the benefits the element provided that gradually gave way to recognition of the serious health hazards it presented.

For obvious reasons, Pittsburgh earned its nicknames of “Iron City,” “Steel City,” and, during the 1970s, “City of Champions.” But the origins of the title of “Radium City” that it acquired in the early twentieth century are far less apparent, and Lubenau and Landa explain clearly how that label came about. It was the result of the entrepreneurial skills and daring of two brothers raised in Pittsburgh, James J. and Joseph M. Flannery. They abandoned their family’s undertaking business to build two industries virtually from scratch. The first was the mining, milling, and smelting of vanadium, a key ingredient in making lighter and stronger steel. The Flannerys founded a firm, the American Vanadium Company, that was headquartered in Pittsburgh and housed downtown in an elegant five-story building.

The Flannerys’ experience with vanadium production was a prelude to the formation of the Standard Chemical Company, whose purpose was to find, mine, extract, and market radium. When their sister was diagnosed with cancer, Joseph Flannery undertook a sustained but ultimately futile attempt to combat her illness by acquiring radium in Europe, the only source of supply at the time. The tiny amount of radium that was available in the United States convinced him to establish a company to produce the element in sufficient quantities to meet demand for medical and other applications.

Radium had been first identified as an element in 1898 by Marie and Pierre Curie. The news of the Curies’ discovery set off a wave of articles, books, and lectures that claimed an abundance of potential uses for the new element, some realistic and many others fanciful. Physicians quickly recognized that radium could be an important advance in treating cancer, but the legitimate benefits were soon overshadowed by many indiscriminate and ill-informed applications, such as injections or consumption of radium solutions for acne, sexual disfunction, and heart disease. The radium craze greatly increased demand for the element, and Joseph Flannery’s company built a state-of-the-art plant in Canonsburg, Pennsylvania, to extract the element from ore. The Canonsburg facility succeeded in substantially increasing the supply of radium in the United States and abroad.

The risks of exposure to radium became evident only gradually, in part because the most serious dangers are insidious. Radium is an “internal emitter” that causes its greatest harm if taken into the body, including severe anemia and other life-threatening afflictions. During the 1920s, the hazards had become apparent enough that professional societies strongly recommended the adoption of protective measures against the improper use of radium.

By that time, the Standard Chemical Company, largely because of competition from cheaper suppliers, had ceased production of radium. Eventually, it was sold at a fraction of its former value.

Radium City is a history of the technical, scientific, business, social, public health, and personal aspects of a once-thriving industry. As such, it makes for an engaging story that the authors admirably bring to light.

J. Samuel Walker is the author of *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (University of California Press, 2000) and other books on nuclear power safety.

Introduction

In 1921, Marie Curie, recipient of Nobel Prizes in physics and chemistry and co-discoverer of radium, visited the United States to receive a gift of one gram of radium from the women of America. Costing $100,000, the gift was presented to her by President Harding at the White House in a ceremony widely covered by the press. The Standard Chemical Company (SCC), a Pittsburgh enterprise founded by James J. and Joseph M. Flannery, produced the radium. After receiving the gift, Marie Curie travelled to western Pennsylvania where she was toured SCC's ore processing and radium refining plants.

Radium City is the story of how the two brothers, undertakers-turned-industrialists, founded the first and largest American company to produce radium and of the company's legacies. It begins not with radium, but another once-rare metal, vanadium. Their purchase of a company manufacturing specialized bolts for steam locomotives led to inquiries about improving the steel used to make the bolts. The answer was a rare metal, vanadium; adding small quantities to steel greatly improved its structural properties. They acquired control of the world's largest, richest vanadium ore body – in Peru – and set about creating a company, the American Vanadium Company (AVC) to mine the ore, ship it to western Pennsylvania where it was processed to extract the vanadium, and develop methods to make vanadium steel. Known as the "miracle alloy," vanadium steel made possible Henry Ford's Model T automobile and was widely used in building the Panama Canal. The AVC was made possible by a team of technical specialists assembled by the brothers. They had a genius for finding and hiring scientists, metallurgists, engineers, and plant managers having the requisite knowledge and experience to make AVC a technological and financial success. The AVC became the blueprint for the SCC.

The brothers' interest in radium arose when their sister was stricken with cancer. At the time, there were only three American physicians experienced in using radium, none in Pittsburgh. To obtain radium, one had to go Europe; but even there it was scarce. The brothers elected to produce radium in the U.S. Once again, they had to create a team of scientists, chemists, engineers, and managers plus physicians and pharmacists, this time to produce radium for medical use.

In Europe, chemical supply houses produced radium as a sideline. SCC was the first company devoted solely to the production of radium. If the SCC was to succeed financially, the brothers needed to create a domestic market for medical radium. This led to an innovative approach combining an extensive in-house medical radium research program, carried out by physicians and pharmacists, with a vigorous marketing effort to inform the American medical community about radium. Commercial production of radium began in January 1913.

As 1913 ended, the brothers faced a threat from an unexpected quarter, the federal government. The Progressive wing of Congress and the Department of Interior were pushing for government control of mineral resources; in the case of radium, this involved withdrawing public lands bearing ore containing radium from commercial claims. This would be a disaster for the SCC. Further, the U.S. Bureau of Mines entered a cooperative agreement with a private organization that eventually engaged in radium production in competition with SCC. House and Senate hearings were held, but they were overshadowed by press coverage of the use of radium to treat a huge tumor on the shoulder of a member of Congress, Rep. Robert G. Bremner of New Jersey. The treatment was unsuccessful and Bremner died during the hearings. To the relief of the Flannery brothers, Congress failed to pass legislation withdrawing public lands bearing ore containing radium from commercial claims.

But 1914 brought more bad news. Most of SCC's radium was sold in Europe because the domestic market was so small. With the start of World War I, European demand for radium dropped sharply, forcing SCC to cut back production. In response, SCC redoubled its efforts to grow a domestic market for medical radium. The war, however, created a new market for radium — luminescent paint for military items such as compasses, watches, gun sights, and dials and instruments on naval vessels and aircraft. By the war's end, SCC was a financial as well as a technological success.

In 1920, the brothers both passed away. James C. Gray, the brothers' longtime legal counsel, was elected president of the SCC. By 1921, SCC had produced over half of the world's radium. This was a remarkable achievement given that radium had been discovered only 23 years earlier and that SCC had been producing radium a mere 8 years. Radium production by SCC ended in 1922 when cheaper radium produced from much richer ore from the Belgian Congo became available from Belgium.

SCC was an extraordinary commercial enterprise. Radium production was America's first nuclear industry. The production and utilization of radium — a radioactive decay product of uranium — was the forerunner of today's production and utilization of uranium for nuclear energy.

When SCC began, there were only three radium therapists in the U.S.; but by mid-20th century there were 3,600 radium therapists, growth that was initiated by SCC. By that time, radioactive materials produced in accelerators and nuclear reactors offered alternatives to radium and more choices in treatment modalities. Radium therapists, already knowledgeable about using radiation from radium, were prepared to utilize them. Medical radium paved the way to today's use of radioactive material in nuclear medicine and radiation therapy. That is a significant, lasting legacy of the Flannery brothers' radium company.

But there were other legacies. For some of its leading scientists, there were tragic health consequences resulting from their working with radium but not knowing radium's dangers — an example of technology outpacing understanding of the technology's risks to health. An unanticipated and unwanted legacy was environmental contamination — the radioactive residues of the mining and milling of ore in Colorado, the radioactive tailings from the extraction of radium from the ore in Pennsylvania, and radioactive contamination of the building where the radium was refined. Remediating these sites would prove controversial, took decades to accomplish, cost millions of dollars, and required government intervention.

What follows is a story of science, technology, engineering, mathematics, and medicine utilized in an innovative commercial enterprise to produce and promote radium for medical purposes. It is an account of the first use of radioactive material in medicine, the role of scientific and medical research to promote its utilization, the effects of radiation on worker health and the environment, and the government's role in these matters. It is about a time when Pittsburgh, known as the iron and steel city, was once called, "Radium City."

Chapter 1: Vanadium

"A better and lighter car."

In a special act passed by the Pennsylvania legislature in 1816 Pittsburgh, then a borough, became a city, the first in western Pennsylvania.[1] Even at this early date manufacturing was eclipsing agriculture within the city. An 1817 enumeration of businesses included iron foundries, blacksmiths, book binders, brewers, copper and tinsmiths, cabinet makers, nail manufacturers, printers, shoe and boot makers, tanners, wagon makers, and weavers. The 259 businesses employed 1,637 workers. Two years later, mechanics and manufacturers organized the Pittsburgh Manufacturing Association to promote local industry. The 1820 U.S. census counted 7,248 persons living in Pittsburgh. The city was bounded on the north and south sides by the Allegheny and Monongahela Rivers which joined at the city's western tip to form the Ohio River. The Allegheny was first bridged in 1818 and the Monongahela in 1819. Plans to supply city water were first proposed in 1818 and by 1828 river water was supplied to city residents and businesses. In 1834, the state legislature established a general system of education and provided funds to establish public schools. Following elections in Pittsburgh to elect school district directors the city opened its first public schools.

The first canal boat arrived in 1829 and beginning in 1834 freight and passengers could travel by canal boat between Philadelphia and Pittsburgh, the boats traveling partly by canals and carried across the Allegheny mountains on an innovative portage railroad.[2] River commerce built up first on the Ohio River where steamboats carried passengers and products manufactured in Pittsburgh to markets west and south of the city.[3] Navigational improvements — damming and building locks —– opened up the Allegheny and other rivers enabling uninterrupted passage for large river packets from river towns to the Gulf of Mexico by way of Pittsburgh and the Ohio and Mississippi Rivers.[4] Pittsburgh was soon connected by railroads; eventually the Pennsylvania, Baltimore & Ohio, New York Central, Buffalo, Rochester & Pittsburgh, and Wabash railroads becoming key links to the national network.[5] The first street railway — powered by horses -— opened in 1859; its cars traveling from downtown at Market and Fifth Streets westward on Penn and Butler streets to the Allegheny Cemetery.[6] Subsequent lines, powered by electricity, stretched to the city's suburbs and interurban trolleys enabled fast and frequent connections to nearby towns.

Besides its rivers Pittsburgh's geography is defined by its hills. Access to hilltops was limited to steep unimproved roadways and paths. In another transportation innovation, a charter was issued in 1867 to the Monongahela Incline Company to construct inclined railways (or "planes") for passengers and freight beginning at the foot of Mt. Washington (a.k.a. Coal Hill) near Smithfield Street.[7] Steam-powered cables hauled the cars to and down from Grandview Avenue on the crest.* It was a resounding success, leading to construction of more inclines in Pittsburgh.[8]

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* Passenger cars continue to climb the Monongahela Incline. It is one of two surviving Pittsburgh inclines, the other being the Duquesne Incline located to its west.

The city's population grew to 49,221 in 1860.[9] The next forty years saw not only continued growth but also a sharp increase in its rate; *annual* growth rates between the U.S. censuses averaging between 3 to 6 percent. The city's population reached 321,616 in 1900. In 1907, Pittsburgh annexed Allegheny City, gaining 130,000 persons in the process.[10] The next census, 1910 counted 533,905 persons living in Pittsburgh making it the eighth most populous city in the U.S. Pittsburgh would remain in the top ten for the next thirty years.

Beginning in 1919 the First National Bank at Pittsburgh published a series of booklets, "The Story of Pittsburgh," portraying the Pittsburgh district's rise in importance as a commercial and financial metropolis.[11] Pittsburgh had become known as the "Iron City" and "Steel City" and for good reason. In 1918, the year World War I ended, Pittsburgh and its surrounding district produced 30% of the U.S. pig iron, the primary component of steel and 60% of the nation's steel, 36% of the nation's finished rolled iron and steel, 45% of its iron and steel pipe and tubing, and 50% of its steel railroad cars.[12] But the bank noted the city acquired another nickname, "Workshop of the World." It reflected the diversity of the city's industrial base that extended beyond iron and steel to the manufacture of coal and coke, glass, electrical equipment, vanadium, radium, cement and concrete, clay products, petroleum and natural gas, other industrial products, and food products. It was also a leader in education, medicine, and finance and banking.

In 1918 ninety percent of the nation's vanadium came from Pittsburgh. Adding small amounts of this once-rare element to steel greatly enhanced its structural properties. Known as the "miracle alloy" vanadium steel made possible Henry Ford's Model T automobile and was widely used in the building of the Panama Canal. Radium, another rare element discovered only twenty years earlier, had become valued for its use as a palliative and in treating cancer. Prior to 1911 the only sources of radium were in Europe and very few American physicians used radium. But by 1918 eighty-five percent of the world's radium was produced in Pittsburgh and a robust community of medical radium therapists in America had grown. This led William J. Holland, Chancellor of the University of Pittsburgh and Director of the Carnegie Museum, to remark that Pittsburgh could be called the "Radium City."[13]

Two companies were responsible for these developments, the American Vanadium Company (AVC) that produced vanadium and the Standard Chemical Company (SCC) that produced radium. Both were founded by undertaker-turned-industrialist brothers, James J. and Joseph M. Flannery. In their lifetimes they were greatly admired in Pittsburgh's business circles for their entrepreneurship and bold innovations. Their vanadium and radium companies stretched from ore fields in Peru and in Colorado to ore mills and laboratories in southwestern Pennsylvania. They had a genius for finding and hiring engineers, scientists, physicians, and managers with the knowledge and experience in diverse fields such as mining and milling ore, chemical engineering, metallurgy, steel making, and medical research. They broke new ground in creating markets for vanadium and radium. Production of vanadium came first and that experience was invaluable when they then ventured into radium production.

So, the story of the Flannery brothers making Pittsburgh the center of radium production begins with their vanadium enterprise.

* * *

Their parents were Michael J. Flannery and Ellen Kirwan, immigrants from County Mayo, Ireland. They married in New York City.[14] After their two children, Lydia B. and Ellen (Nellie) A., were born they moved to Holliday's Cove, West Virginia (now part of Weirton) where their first son, James J., was born in 1855 (figure 1.1).[15] Afterwards, the family moved to a home on Grant Street, Pittsburgh where three more sons were born, John S. in 1858 (figure 1.2), Peter K., in 1861 (figure 1.3), and Joseph M. in 1867 (figure 1.4).[16]

Michael and Ellen saw to their children's education. Their daughters attended Our Lady of Mercy Academy, the first private academy for girls in Pittsburgh. James and Joseph attended the Christian Brothers' Parochial School and public school and Peter and John attended St. Paul's Parochial School.

James took his first job at age seven carrying water up five flights to a photographer's studio.[17] He later learned the carpentry trade. John, at age 13, went to work for a Pittsburgh undertaker, Reilly and Burns, on Grant Street. In 1874, James and John combined their trades – carpentry to build coffins and the management of funerals — to form their own undertaking firm, James J. Flannery & Bros. Company located on Grant Street between Fifth and Sixth Avenues where the Frick Building now stands. As part of their funeral services, the company provided carriages for transporting the deceased and mourners to the cemetery. James expanded this to a livery that provided carriages for hire, an early example of his looking beyond undertaking for other opportunities for advancement and business.

The year 1877 opened an opportunity for James to enter politics when Democrats in the city's Third Ward nominated him to fill a vacant Pittsburgh Select Council seat. Described as honest, capable and popular, he won the special election handily defeating his Republican opponent 67 to 3.[18] He was twenty-two years old. Three years later Third Ward Democrats chose him for Ward President.[19] In 1881, after the Third Ward nominated him to run for the City Common Council, he defeated the Republican incumbent in a close contest, 215-212.[20]

Disaster struck in December 1885 when natural gas explosions struck three buildings on Grant Street including the two housing James Flannery's family and his funeral and livery businesses.[21] One person died and two others were severely injured. Flannery's wife and children escaped unharmed. His financial loss totaled $10,300 but it was covered by insurance that he had prudently purchased.

Another disaster, the Johnstown Flood occurred on May 31, 1889 following the breakage of a dam on the Little Conemaugh River leading to over 2,200 deaths. Some corpses were washed miles downstream. One of the earliest needs in the aftermath was undertakers to prepare bodies for burial. On June 1st James Flannery presided over a meeting calling Pittsburgh undertakers to respond to the crisis.[22] Almost every firm responded and 79 undertakers were pledged. Arrangements made to transport them, their "kits," and other mortician supplies. The first contingent — 55 undertakers led by Flannery — arrived the next evening in Johnstown.[23]

A week later, this relief effort became marred by a public row over who was leading the effort and an accusation that the men had become drunk, in particular, an agent of an embalming company.[24] Another Pittsburgh undertaker, W. H. Devore, levied the charges. In response, the undertakers met in Flannery's office. The agent denied the drunkenness charge and was supported by the undertakers. While Devore had been deputized by the state Board of Undertakers to manage the undertakers they agreed it was Flannery who initiated and organized the effort. The undertakers had volunteered their services but Devore was accused of sending bodies to his establishment in Pittsburgh. Tellingly, Devore's own son sided against his father. The matter closed in favor of Flannery and while a knock-down fight had been averted, Flannery afterwards admitted "the Irish in me did boil." The next day a second contingent of undertakers reported to Flannery and was sent to Johnstown. James Flannery was fast gaining a reputation for unselfishness and strong leadership.

Meanwhile, Peter and Joseph matriculated at Holy Ghost College (now part of Duquesne University), but did not graduate. Instead, they joined Joseph and John in the undertaking business. In 1897, Peter and Joseph established another Flannery undertaking establishment, first locating it in McKeesport and then in Braddock where they made the acquaintance of prominent steel manufacturing businessmen. The brothers' association with the steel men probably planted the seed for James and Joseph's interest in steel products for the railroad industry.

With the undertaking company prospering James and Joseph began looking for other business opportunities. In 1900 they organized the Meadowlands Coal Company, James becoming Treasurer and Joseph, Secretary and in 1903 they expanded their investments to railway supply businesses.[25] Peter died in 1911 following a long illness.[26] John, meanwhile, continued to run the undertaking business, later remarking. "[I] was left to do the 'body snatching' and keep the sure thing, undertaking, a going concern".[27]

One of the brothers' investments was purchase of a bolt manufacturing company in Bridgeville, Pennsylvania in the Chartiers Creek Valley, south of Pittsburgh, which they reorganized as the Flannery Bolt Company (figure 1.5). James was president and Joseph served as secretary.[28] The company produced staybolts, specialized bolts used in the construction of steam locomotives to connect the walls of the firebox, where wood, coal, or oil was burned, to the locomotive boiler shell. The brothers obtained control of a new, patented version, the "Tate Flexible Staybolt" (figure 1.6).[29] It became a resounding commercial success — ninety-five present of American railroads eventually adopted it as their standard for steam locomotives. [30]

Having found that design changes could improve staybolts, the brothers asked if further improvements might be possible by improving the metal used to make the bolts?[31] Joseph traveled to Europe to visit steel manufacturing centers where European metallurgists provided the answer — steel containing vanadium.[32]

Vanadium, a metallic element, was discovered twice.[33] The first discovery was claimed in 1801 by a Spanish mineralogist, Andres Manuel del Rio, who prepared a number of new element salts from a material contained in brown lead (now called vanadite) from Zimapan in Mexico. The element was named erythronium ('red') after del Rio noted that most its salts turned red on heating. However, a Frenchman, Hippolyte Collett-Descotils, disputed del Rio's claim, and del Rio withdrew it. In 1831 the Swedish physician and chemist Nils Gabriel Sefström isolated an oxide of a new element when working with iron ores. Because of its colorful compounds, he named it vanadium for the Scandinavian goddess of love and beauty, Freyja the Vanadis. Also, in 1831 the German chemist Friedrich Wöhler came into possession of del Rio's brown lead and confirmed his discovery of vanadium, but Sefström's name for the element, vanadium, remained.

Vanadium is widely distributed in the earth's crust but does not readily form ore deposits. Because supplies of vanadium were limited it was costly, for example, in 1892, vanadium was priced at $4,792 per pound.[34] Consequently, its use was restricted to experimental work. In 1896, chemist Narcisse Alfred Helouis reported to the French Society for the Encouragement of National Industries the results of his tests of vanadium on steel and other metals.[35] The Firminy Steel Works in France experimentally used vanadium steel to make armor plate and demonstrated its superiority to ordinary steel but found it difficult to make.[36] In England John Oliver Arnold, Professor of Metallurgy, University College of Sheffield, conducted additional tests of vanadium steel.[37] In 1904, H. Riall Sankey and J. Kent Smith published a comprehensive report on chrome-vanadium steel that became recognized as a landmark paper on vanadium steel showing that small amounts of vanadium, less than one percent, added to ordinary carbon steel greatly increased its strength and markedly improved its resistance to metal fatigue.[38]

* * *

The most promising domestic source of vanadium was a vanadium and uranium-bearing mineral, carnotite, found in the American southwest. The Flannerys began acquiring mining options in southwestern Colorado and eastern Utah.[39] Then, in 1905, while at a convention in Manhattan Beach in New York City, James Flannery and his son, J. Rogers, met Spanish visitors who informed them of vanadium ore in Peru.[40]

The ore lay in the Pasco region north of Peru's capital, Lima, and east of the Andes Mountains (figure 1.7). High in elevation, the region was rich in mineral resources; silver was found in 1630 followed by discoveries of copper, lead, bismuth, and zinc. In the late 19th century the Peruvian government sponsored the construction of the extraordinary Central Railway of Peru, a.k.a. the Oroya Railway. For many years it was the world's highest standard gauge railroad, crossing the Andes to provided access from Pasco to Lima's port city, Callao.[41] Afterwards, most of the mining in the region came under the control of an American syndicate, the Cerro de Pasco Corporation.[42] Of the few remaining independent mining and smelting operations the most prominent were those controlled by Eulogio Erasmus Fernandini y Quintanna.[43] His holdings included fields of asphaltite, a naturally solidified petroleum mineral locally used as coal. In 1894 asphaltite in the Yauli district was found to contain vanadium and was briefly mined by a French company but operations ceased in 1899.[44]

In late 1905, to investigate the potential of this deposit, the Flannerys sent to Peru a business associate and electrical engineer, Alfred J. Thompson, and a 1902 Lehigh University metallurgical engineer graduate employed by Pittsburgh Testing Laboratory, D. Foster Hewett (figure 1.8). After detraining from the Oroya Railway at Yauli, they trekked through snow-covered mountain passes at lung-searing 16,000-foot elevations to reach the Yauli ore deposit.

Hewett found the vanadium concentration in the asphaltite too low to justify mining. He and Thompson turned back to Lima to return home.[45]

At this particular moment, a work party sent by Fernandini to search for coal for his smelter near the hacienda Quisque discovered another asphaltite deposit containing vanadium. Antenor Rizo-Patron Lequérica, the metallurgist in charge of the smelter, found the asphaltite contained high levels of vanadium, 9.5 to 15% in the form of vanadium sulfide.[46] After his findings were confirmed by the Peruvian Corps of Engineers Fernandini established his legal right to mine the ore but made no public announcement of it. Nonetheless, the discovery became known in the Peruvian scientific community. Jose J. Bravo, a Peruvian geologist and paleontologist, on learning of Thompson's and Hewett's presence in Lima and their interest in vanadium visited them as they awaited the next boat to return to America, to inform them of the Quisque discovery. Thompson was inclined to ignore this late news and head for home but Hewett argued, "The Flannerys sent us 4,000 miles down here to look for vanadium, and I'm going to keep faith with them. We're not going back until we look at this prospect."[47] Once again they traveled the Oroya railroad to the Pasco region, this time riding horses over the final twenty-five miles from the railroad station to the Quisque ore site. There, Hewett found an extensive, rich vanadium ore body. Upon returning to Pittsburgh, on February 27, 1906 Hewett sent a letter to Joseph Flannery describing the characteristics of the ore body, the results of the chemical analyses of the ore, and the logistical requirements and costs to mine and ship the ore to Pittsburgh. He concluded by describing the ore body as "the richest deposit of vanadium known in the world" and recommending purchasing the mining rights.[48]

While Thompson and Hewett were in Peru, the Flannerys organized a new company to handle vanadium mining and production. The American Vanadium Company (AVC) was incorporated in New Jersey and capitalized at $700,000; board officers were James J. Flannery, Joseph M. Flannery, Harry A. Neeb, a Pittsburgh businessman,[49] and Alfred J. Thompson.[50] On May 24, 1906 Hewett again wrote to Flannery updating him on developments in Peru, verifying Fernandini had clear title to the ore, refining his cost estimates, and confirming his recommendation to acquire the mining rights adding "this property will repay many times the cost of acquiring it."[51]

The Flannerys put aside their carnotite mining plans in Colorado and Utah in favor of utilizing the Peruvian ore, now named patronite after its discoverer.[52] James Flannery dispatched Joseph to Peru to acquire the mining rights. What happened next became a legend in the family and in Pittsburgh business circles.

Eulogio Fernandini (figure 1.9) was born in Peru, educated in Austria and Germany, and returned to his native country. Like the Flannery brothers he became engaged in a diverse mix of business interests that included mining and smelting ores, ranching, farming and banking.[53] He collected gold coins; after his death in 1947, Peruvian tax assessors found antique chests filled with nearly two million dollars of the coins.[54] Flannery may have learned of Fernandini's obsession with gold. He went to Peru carrying a bank's letter of credit for $20,000 and on arrival converted the letter of credit to gold coins that he placed into a carpetbag. When he met

Fernandini, Flannery emptied the carpetbag's contents onto a table and divided the pile into two. Pushing one half towards Fernandini, he said that half was for the rights to mine the ore. Pulling the other half towards himself, he said that half was to stay in Peru to be used to develop the mine and pay Fernandini to oversee the operations.[55] Fernandini, aware that European interests were prepared to make an offer for the ore, demurred. Flannery sweetened the deal by offering Fernandini the position of vice-president and a ten percent stake in the newly organized American Vanadium Company (AVC),[56] at no cost to Fernandini but worth $70,000 making the total value of the offer $90,000.

Afterwards, Joseph Flannery did not publicly mention his offering company stock to Fernandini. In an account given to a Washington newspaper reporter, Flannery said that on their way to the lawyers' office to record the agreement, a messenger delivered a telegram to Fernandini from a British syndicate offering $100,000. He showed it to Flannery and then tore it up, telling Flannery, "It is a good offer, but too late."[57] Other accounts of the negotiation varied; according to one, Fernandini initially agreed to the offer of $10,000 for the mining rights and then learned an offer $200,000 had been made by a foreign group but Flannery insisted on Fernandini keeping his word on their agreement. After Fernandini acceded to this, Flannery added to the agreement a 10% stake in the company to Fernandini. [58] J. Rogers Flannery, in his account, declined to affirm or deny the story about the gold coins and stated Fernandini received a 25% share of the American Vanadium Company.[59] Although the exact details may never be known, the bottom lines were: (1) the final agreement included payment to Fernandini of $10,000 in gold for the mining rights, a 10% share of the stock in the new company, and his appointment to the company board as vice-president[60] and (2) the Flannery brothers now controlled the world's richest vanadium ore body.[61] It was on another continent, at an elevation of 16,200 feet (figure 1.10). Building this mining venture from scratch presented formidable challenges, not the least of which was the task of delivering the ore to the U.S.

Mining the ore had to be left to indigenous workers used to laboring in the thin air. The ore was roasted in furnaces to burn off excess sulfur, a process that increased the concentration of vanadium and reduced the ore's shipping weight. The roasted ore was sacked and carried to the nearest station of the Oroya Railway by the regional beasts of burden, llamas. The Oroya Railway delivered the ore to Callao. From there ships carried the ore around Cape Horn to Philadelphia where it was transferred to railroad cars that took the ore to the AVC plant in Bridgeville, built next to the Flannery Bolt Company factory.[62]

Beram D. Saklatwalla was put in charge of the Bridgeville plant. A native of India, he earned scholarships to attend the University of Berlin where he received a Doctor of Engineering degree.[63] He met the Flannerys by chance while on a business trip to the U.S. and they hired him on the spot.[64] His responsibility was to develop a process to extract vanadium from the patronite.

Vanadium forms a large variety of compounds having widely different chemical properties that made it a challenge to extract from ore. Wet chemical processing of the ore resulted in large losses in recovery of vanadium.[65] In a timely development, the Niagara Research Laboratories (NRL) in Niagara Falls, New York was experimenting with electric arc furnaces to process ore. AVC contracted with NRL to smelt the patronite ore using their electric arc furnaces. In the meantime, Saklatwalla took steps to develop other ore treatment methods at its Bridgeville plant. The experimentation led to a new process that required rebuilding the Bridgeville plant. In 1913, the Flannerys engaged Frederick J. Osterling, a well-known Pittsburgh architect, to design the new buildings. (figures 1.11 & 1.12).[66]

* * *

The Flannerys were not the only Americans interested in vanadium. In Michigan, Henry Ford was envisioning lightweight automobiles, called "runabouts," as the future for automobiles.[67] To make them he needed steel that was stronger and resistant to metal fatigue. Ford and his engineering staff knew that vanadium steel might make this possible but had not found anyone to make a convincing argument that it could be done.[68]

The Flannerys' link to Ford was an Englishman, J. Kent Smith. Smith's father, a noted metallurgist, owned a steel mill in Sheffield.[69] At age nine years, Smith began working at his father's mill. When he was twenty-one, his father died and he moved to the University of Sheffield where he was appointed an assistant to John O. Arnold, Professor of Metallurgy. Smith's 1904 paper, co-authored with H. Riall Sankey, on vanadium steel established his expertise on the subject and Joseph Flannery very likely learned of him when he visited European steel makers.[70] Subsequently, Smith came to the United States, established a laboratory in Canton, Ohio, and traveled widely in the U.S. advocating vanadium steel's advantages. The Flannerys brought him into AVC making him the company's chief metallurgist. In 1906, Smith met with Ford in Detroit to brief him and his engineers on the performance specifications for vanadium steel. After the meeting, Ford remarked to Charles Sorenson, his assistant production manager, "Charlie, this [vanadium steel] means an entirely new design requirement. We can get a better and lighter car and cheaper car as a result of it."[71]

The problem facing Ford and the Flannerys was finding a steel maker to make the alloy.[72] Steel-making was an intensely competitive industry and vanadium steel was notoriously difficult to make. Given these factors coupled with a seemingly small market for vanadium steel meant there was little interest in risking investment to make it. But in Canton, where Smith had his laboratory, officials of the United Steel Company, which had recently built a new steel mill saw in vanadium steel a market niche that the company could fill.[73] Fred Griffith, the company chemist supervising the company's open-hearth furnaces, was instructed to work with Smith to solve the problem of making vanadium steel that consistently met Ford's specifications. After considerable experimentation and false starts, on March 28, 1907, Smith and Griffith proved it could be done by pouring three consecutive heats of vanadium steel meeting Ford's specifications. Present for the demonstration was an impressive congregation of industrialists: James and Joseph Flannery and A. J. Thompson of the AVC, Henry Ford and C. Harold Willis of the Ford Motor Company, Frederick Becket of the Electro-Metallurgy Co., Niagara Falls, NY, Peter Reese of the Carnegie Steel Company armor plate division, a representative of the Standard Oil Company, and Oliver Transue of the Transue and Williams Company, an Ohio forging and stamping mill.[74] The gathering of these industrialists was noted by the Canton newspaper and a group photo was taken (figure 1.13).[75] Ford was now satisfied and placed an order for $750,000 of vanadium alloy steel ($20,200,000 in 2018 dollars), the largest order of such steel up to that time.[76] The United Steel Company wasted no time advertising the availability and advantages of vanadium steel and published an illustrated brochure on the product that same year.[77]

In October 1908, the first Ford Model T's rolled off the assembly line at a retail cost of $850, a price that eventually dropped to $290.[78] Fifty percent of the steel in the Model T was vanadium steel – the crankshaft, gears, driveshaft, connecting rods and springs.[79] In his advertising, Ford highlighted his use of vanadium steel. Over the next 19 years, more than 15 million Model T's were manufactured (figure 1.14). The Model T revolutionized Americans' travel habits; vanadium steel made the Model T possible and the Flannerys supplied the vanadium.

Orders from Ford for vanadium steel provided a strong sales base for vanadium but to fully utilize AVC's production capacity it needed to create new markets. Joseph Flannery traveled to the Panama Canal construction site and met with the engineers convincing them and General George Washington Goethals to incorporate vanadium steel into the hinges for the lock gates.[80] By the end of 1911, in addition to the 569 tons of the vanadium steel in the hinges, another 500 tons of vanadium steel in miscellaneous castings was ordered for construction of the canal and in 1913 more vanadium steel was ordered for other canal structures.[81] To help publicize vanadium steel AVC started a company journal, *American Vanadium Facts*. The journal cited other uses for vanadium steel, e.g. in railroad locomotives, airplanes, armor plate, and motorcycles. [82] In January 1913, *American Vanadium Facts* illustrated Ford's Model T, plus cars and trucks made by fifteen other manufacturers characterizing them as "only a few of the leading 1913 Pleasure and Commercial Vehicles in which Vanadium Steel is extensively used."[83] J. Kent Smith proved to be an effective advocate by writing many of the company's advertising brochures that extolled the virtues of vanadium as the "Miracle Alloy" (figure 1.15).[84] Besides steel vanadium could also be alloyed with other metals such as manganese, aluminum, and copper.[85] The onset of World War I in 1914 increased the demand for vanadium steel, specifically for armor and heavy ordnance.[86]

The company's promotion of vanadium expanded to medical use of its chemical compounds. A sanitarium, "The Vanadium," was established at the former Rider Hotel in Cambridge Springs, Pennsylvania.[87] Advertisements for the hotel highlighted the availability of "Vanadium Treatment discovered and perfected by the eminent French scientist, Helouis…. recognized by the medical profession of Europe" adding that the treatment is under "the direction of physicians who have personally studied with Helouis and other practicing physicians in Paris and London."[88] Narcisse Alfred Helouis, a French chemist known for his research into the effects of adding vanadium to steel, claimed to have begun his research under a Commission from Emperor Napoleon III in 1865 and to have discovered vanadium compounds had medical value.[89] In September 1910 Helouis came to The Vanadium to take charge of the "vanadium treatment" program for hotel guests. The AVC established a subsidiary, Vanadium Chemical Company, to promote and sell vanadium medical products. Dr. Francis M. Turner was retained as General Manager.[90] "Helouis Vanadium Compounds For Therapeutic Use," were touted as "Bases of Vanadium for carrying active Oxygen into the system and for external application." Products included Vanadiol and Phospho-Vanadiol for uptake by mouth, Vanadium Solution for hypodermic and intravenous use, Vanadioseptol, an antiseptic and germicidal solution, and Vanadoforme, a surgical dusting powder (figure 1.16).[91]

* * *

While the Bridgeville plant housed AVC's production facilities, corporate and sales offices for AVC and its subsidiaries were in the Frick Building in downtown Pittsburgh, built by Henry Clay Frick, Pittsburgh industrialist and financier. It also housed offices of the brothers' other enterprises that included real estate. The Flannery brothers were a major force in developing the Oakland section of the city. In 1901, James Flannery began constructing a modern six-story building on the south side of Forbes Avenue between Meyran Avenue and Atwood Street. Costing $350,000 ($10,500,000 in 2018 dollars) the Iroquois Apartment Building included features new to Pittsburgh apartment buildings – electric lighting, elevators, independent water supply, steam heating and refrigerating plants, stores, and a bank.[92] Frederick Osterling, who later designed the rebuilt AVC plant in Bridgeville, was the architect.

Next was the purchase of the corner lot on Forbes Avenue and Meyran Avenues for a building to house the Flannery brothers' AVC and other company offices, again engaging Frederick Osterling to design it. Completed in 1911, the brothers named it the Vanadium Building and spared no expense in its construction. The steel-framed building featured five floors serviced by an elevator (figure 1.17). Visitors entered the building through an impressive colonnaded entrance on Forbes Avenue. Its exterior was covered by heavily ornamented terra cotta. The interior was lavishly furnished with marble stair steps and marble veneers for the stairwell wainscoting and hallway walls. The Oakland Savings and Trust Company, another Flannery business, filled the first floor.

When the Flannery brothers leased office space in the Frick Building, each day they entered the lobby their eyes fell upon a large stained-glass window on the wall opposite the entrance. Designed by John La Farge the window depicted Fortuna, the Roman Goddess of Fortune spinning her wheel and, by its presence, reminded all who entered of Frick's good fortune and wealth (figure 1.18). [93] With this in mind that the Flannerys commissioned the Rudy Brothers Studio in Pittsburgh to create a stained-glass window as a centerpiece for their building entrance. J. Horace Rudy (figure 1.19) was the studio's designer.

After acquainting himself with the story of the Flannery brothers' vanadium venture Rudy chose to tell it in a nine by ten-foot stained glass window (figure 1.20). The central figure at first glance appears to be an angel but is Freya Vanadis, the Norse goddess of love and beauty who in Celtic lore wore a robe of falcon feathers and had wings. Above her she holds a plaque with the word, "VANADIUM." To the right of her is a bearded man sitting on an anvil and holding a hammer, the Greek god Hephaestus, the gods' blacksmith and god of metals and metallurgy.[94] To the left is a young man with a miner's pick, Prometheus, a Greek mythological figure linked to fire and the discovery of metals.

La Farge's window told of Frick's wealth; Rudy's window told how the Flannery brothers came to theirs —– their learning of the value of vanadium to make better steel, the discovery of the world's richest body of ore of the metal and their mining of it and the discoveries by metallurgists of how make vanadium steel alloys. Frick's and the Flannery brother' windows shared a common feature: each was mounted opposite the entrances to the buildings so that visitors would be sure to see them.[95]

American production of vanadium steel grew from 800 tons in 1905 to 25,844 tons in 1910. In 1912, AVC alone produced 90,000 tons.[96] By 1914, the company was producing about 90 percent of the world's supply of vanadium and paid stockholders annual dividends for stockholders as high as 40 percent.[97] Its extraordinary financial success attracted the interest of other investors. In 1915, J. Leonard Replogle joined AVC as Vice-President and General Manager of Sales.[98] Replogle had started as an office boy at age 13 at the Cambria Steel Company rising to vice-president and manager of sales at age 38 before moving to AVC. In 1916, he headed a syndicate that purchased AVC paying $1,000 per share, ten times their original cost.[99] In the new organization, the Vanadium Corporation of America (VCA), James Flannery became chairman of the board, Replogle became president, Fernandini remained vice-president, and Saklatwalla became a board member. For the original AVC investors who held shares having a par value of $100 the sale resulted in an enormous profit.

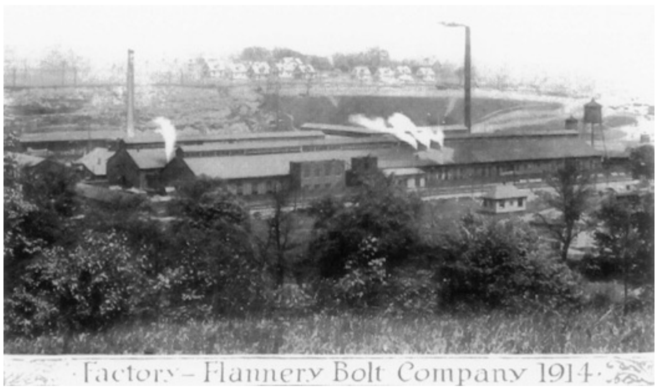
In Peru, Fernandini's 700 shares were now worth $700,000, shares acquired at no cost thanks to his successful negotiations with Joseph Flannery. But even before this, Fernandini had been impressed by Flannery — in 1906, Felipe De Lucio, his chief mining engineer, recalled:

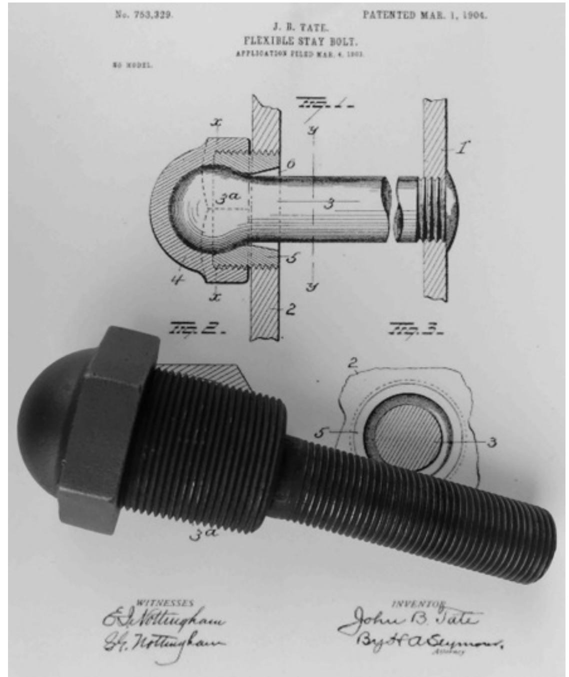
> He [Fernandini] is better disposed to Mr. Flannery, to make business with, than anybody else. He always likes to recollect Flannery's straightforward ways…never heard him speak so openly of anybody.[100]

In 1916 when the VCA bought out AVC, the Flannery brothers were engaged in commercial production of another rare element, radium, an endeavor that would gain the Flannery brothers even greater acclaim. The AVC's experience —– mining and shipping ore from a remote location, developing the chemical engineering process to extract the metal, financing and building the supporting infrastructure, creating the markets for vanadium products, and assembling the technical, marketing, and administrative teams to carry out these tasks — would provide the blueprint for their radium venture.

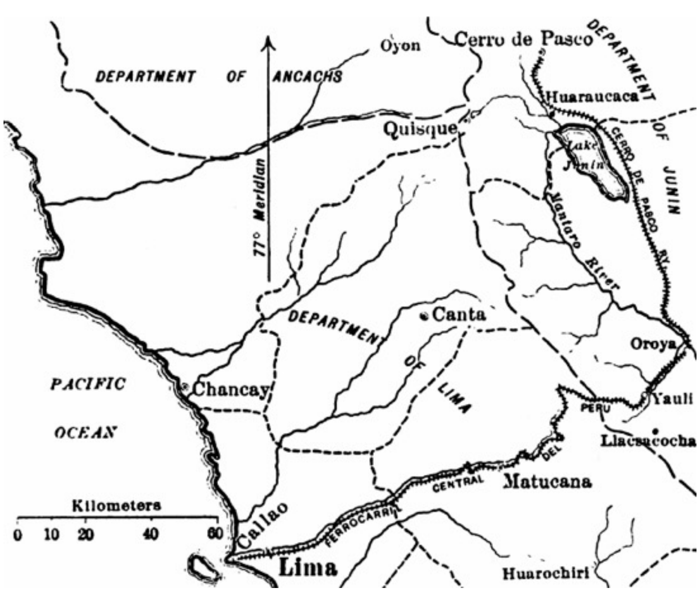
1.1., 1.2. Left, James J. Flannery, oldest of the Flannery brothers. Right, John S. Flannery. *JOL*

1.3 Left, Peter K. Flannery. *NA* 1.4 Right, Joseph M. Flannery, youngest of the brothers. *JOL*



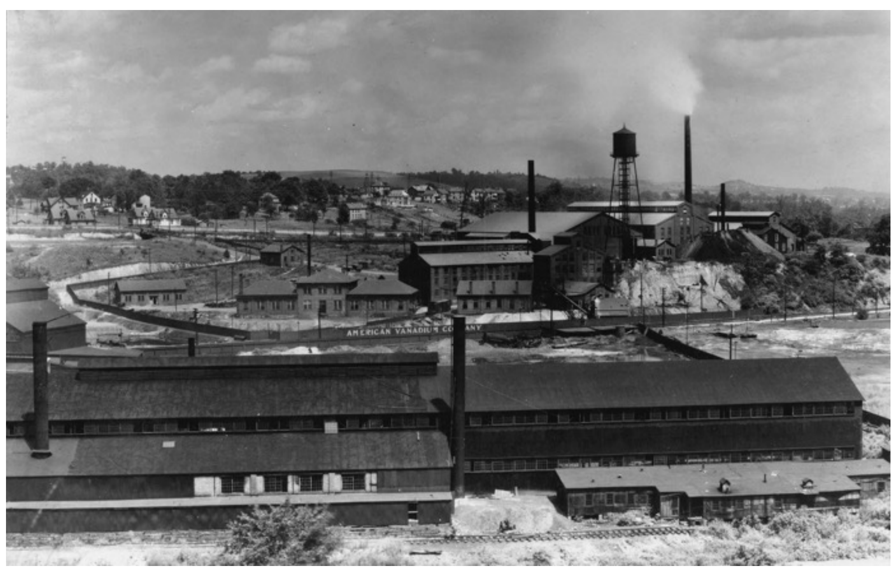


1.5 Left, the Flannery Bolt Company, Bridgeville, Pennsylvania organized in 1904. *BAHS*
1.6 Right, a Tate Flexible Staybolt overlaying its March 1, 1904 patent. *JOL*



1.7, 1.8 Left, map of the Pasco region of Peru showing Peru's capital, Lima and its port city, Callao, and the railroad that crossed the Andes mountains to connect them to Yauli, Oroya, and Cerro de Pasco, the Pasco region capital. Quisque, site of the patronite vanadium ore, is southwest of Cerro de Pasco. Right, D. Foster Hewitt, 1902 Lehigh University metallurgical engineer. *LU*

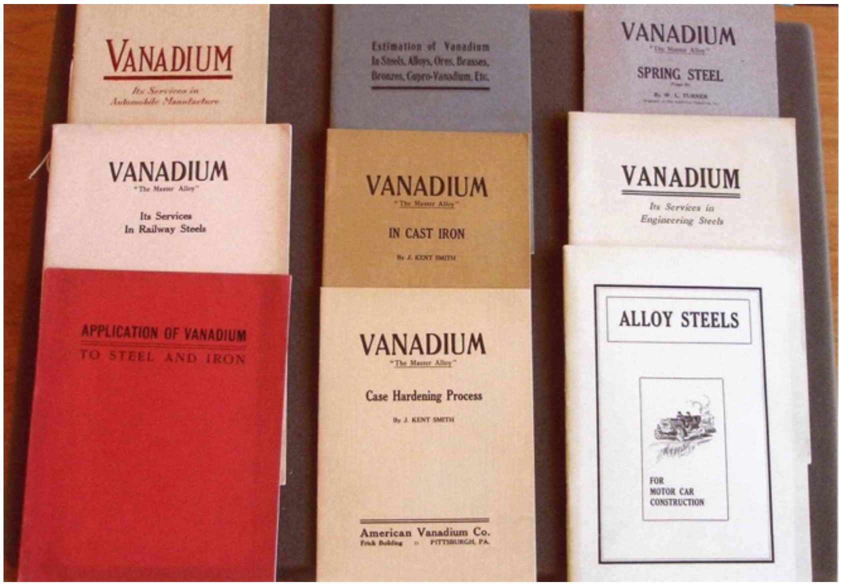
1.9 Left, Eulogio Erasmus Fernandini y Quintanna. *JOL*
1.10 Right, the first mining camp, Campamento de Arriba, (High Camp), elevation 16,200 feet. *SHI2*

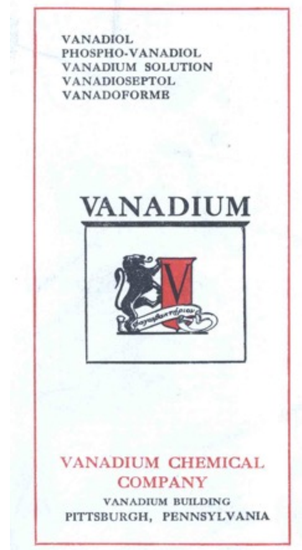



1.11 Left, Frederick Osterling, well-known Pittsburgh architect. *JOL*
1.12 Right, American Vanadium Company plant, Bridgeville Pennsylvania, ca. 1913. *SHI2*

1.13 March 28, 1907, at the United Steel Company plant in Canton, Ohio. Left to right: Frederick M. Beckett, Electro-Metallurgy Co., Niagara Falls, New York; J. Kent Smith, AVC Chief Metallurgist; Alfred J. Thompson, AVC Sales Manager; Joseph M. Flannery; James J. Flannery; Oliver Lenhart, affiliation unknown; Henry Ford, R. M. Lewis, General Steel Company, Canton Ohio; Fred J. Griffith, Chief Chemist and Open-Hearth Supervisor, United Steel Company. *THF*

1.14 In 1927, the 15th million Ford Model T was made. Henry Ford is nearest the camera. *THF*





1.15 Left, covers of AVC's advertising brochures on vanadium and vanadium alloys, many written by J. Kent Smith. *HML* 1.16 Right, cover of a brochure advertising vanadium medicine. *CPP*

1.17 Left, an early view of the Vanadium Building when it bore that name over the entrance. *CPP* 1.18 Right, the Roman goddess Fortuna spinning her Wheel of Fortune in a stained-glass window by John La Farge located in the lobby of Frick Building, Pittsburgh. The Flannery brothers saw this window each morning when they entered the Frick Building that housed the American Vanadium Company offices prior to their relocation to the Vanadium Building. *JOL*

1.19 J. Horace Rudy, designer of the Vanadium Window. *HHC1*

1.20 The Vanadium Window. *HHC2*

Chapter 2: American Radium
"Tarter and Splint in the Thumb."

The discovery of radium, reported in December 1898, came on the heels of Roentgen's discovery of x-rays published in January 1896. Both fascinated scientists and the public. X-rays were a previously unknown radiation emitted by high voltage tubes. X-ray radiation was invisible to the eye but paradoxically made invisible things such as bones inside a body visible. The obvious value of x-rays for medical practitioners was noted in the very first public article on the discovery.[101] The public imagined other possibilities:

The Roentgen Rays, the Roentgen Rays
What is this craze?
The town's ablaze
With the new phase
Of x-ray's ways
I'm full of daze
Shock and amaze;
For nowadays
I hear they'll gaze
Thru cloak and gown — and even stays
These naughty, naughty Roentgen rays. [102]

Radium was even stranger because it not only emitted invisible radiation similar to Roentgen's x-rays, it emitted light and was thus capable of making things in the dark visible.[103] Unlike x-rays, which came from an energized electrical tube, radium did these things without electrical stimulation. Furthermore, radium emitted heat.[104] Radium's properties led to wild public speculation about how it might be used, for example, for boiling eggs, radium cocktails, luminous roulette wheels and gambling chips, and bicycle lights just to name a few.[105] An enthusiastic journal editor in 1903 suggested putting radium into street lamps to "get a mild moonglow, while saving gas and electricity."[106] The "x-ray craze" had been joined by a "radium craze."[107]

Nonetheless, there were potential practical uses. For example in Philadelphia, University of Pennsylvania physicist George F. Barker brought the first radium to the U.S. in 1899 from the de Haën laboratory in Hannover, Germany and used it to make radiographic images similar to those made by x-rays.[108] Reports from Pierre Curie and other experimenters that radium caused skin burns opened the possibility of medical applications.[109] In 1901, Pierre Curie loaned a radium source to Dr. Henri Danlos in Paris who used it to successfully treat a case of lupus vulgaris, the earliest known case of radium being successfully used to treat disease. In addition to treating other diseases such as cancer radium was found to be an analgesic leading to its use as a palliative.[110] These early successes led to a new medical specialty, radium therapy.

* * *

In 1909, the Flannerys' sister, Ellen (Nellie) Murphy, was diagnosed with cancer of the uterus.[111] Joseph Flannery already knew of the medical use of radium when he learned of his sister's cancer.[112] Earlier, a relative of a friend had been sent to Johns Hopkins University for cancer treatment and Jose Baxeres de Alzugaray, an Argentine metallurgical chemist involved in development of vanadium steel and an acquaintance of Flannery, suggested radium therapy. At Flannery's request, de Alzugaray arranged for the Curie Laboratory in Paris to send radium to Johns Hopkins.[113]

Most of the progress in radium therapy was taking place in Europe.[114] So upon learning of his sister's diagnosis, Flannery sent a physician to Europe who confirmed that radium was being used there for medical purposes but found it impossible to obtain any.[115] In the U.S., only three physicians had made long-term commitments to radium therapy, Francis H. Williams in Boston, Howard Kelly in Baltimore, and Robert Abbe, in New York City.[116]

In late 1900 or early 1901, Williams used a radium source one to treat a case of lupus, a skin disease that he had previously treated successfully with X-rays. Although the radium application was not successful Williams became, if not the first, one of the earliest physicians to attempt using radium therapeutically.[117] Kelly, a widely respected physician renowned for his pioneering work in treating gynecological cancer, became chair of Gynecology and Obstetrics at Johns Hopkins medical school in Baltimore in 1889 and was one of the school's founders. Kelly had become acquainted with radium therapy and beginning in 1907 began acquiring radium for his private hospital, the H. A. Kelly Hospital in Baltimore.[118] Robert Abbe, a New York physician and plastic surgeon, became interested in radium therapy because of his concern about the disfigurement that often was a result of radical surgery to treat cancer. In 1903, he had secured his first radium from the Curies and by 1910 he had treated 500 cancer cases with varying degrees of success.[119]

Williams, Kelly, and Abbe were eminently qualified in radium therapy but Flannery was seeking a Pittsburgh radium therapist; there was none. As an alternative could radium be brought to Pittsburgh?

* * *

All of the radium in the United States came from Europe. It is a radioactive decay product of uranium. The radium that the Curies discovered was extracted from the residues of the mining of pitchblende, a uranium ore, in Joachimsthal in the Bohemia region of Austria. Joachimsthal's mines had been a source of silver and other metals and had an historical connection to the U.S. Beginning in the early 16th century; the mines' silver was minted into coins, *thalers*, from which name of the American monetary unit, *dollar* is derived.[120] Thanks to the intervention of the Academy of Sciences of Vienna and outside funding, the Curies had been able to obtain the necessary quantities of the pitchblende residues for their research at reasonable cost.[121] Also, the Curies entered into a benevolent arrangement with a French commercial chemical company, Armet de Lisle, which performed the preliminary processing of the pitchblende ore thus freeing the Curies to work on refining of the radium.[122] The arrangement continued until 1903 when Austria, concerned that foreign interests were exploiting an Austrian resource for commercial profit, placed an embargo on the export of uranium and the mine residues.[123] An exception was made for the French in recognition of the Curies' relationship with the Austrian Academy of Sciences. For others it was becoming increasingly difficult to obtain radium sources. In these circumstances, Europeans were turning to America for a source of radium.[124]

American deposits of pitchblende were limited. More common were occurrences of carnotite, the vanadium-uranium ore that first attracted the Flannery brothers' attention because of its vanadium content.[125] A small attempt to extract radium from carnotite was mounted in 1903 in Denver but nothing further came from that effort.[126] In Buffalo, New York, the discovery of radium drew the interest of Stephen T. Lockwood, an attorney. In 1900, he visited the carnotite region of southeastern Utah and southwestern Colorado, and then organized The Rare Metals Reduction Company to extract radium.[127] It was an audacious decision given his lack of knowledge of chemistry. To address this deficiency, he wrote to the persons most expert in radium chemistry, Pierre and Marie Curie.[128] His letter provoked a discussion between the Curies about whether to patent the process or publish their research without reservation. Both agreed on the latter, a famous decision, and Pierre sent his reply to Lockwood conveying the technical information.[129] Lockwood obtained his carnotite ore from mines in Richardson, Utah and shipped it to Lackawanna, New York where an extraction plant was built. By September 1902, Lockwood had produced a barium-radium sulfate mixture of sufficient strength to create a radiograph showing a metal key, coin and washer.[130] His work drew the interest and financial support of mining magnate Thomas F. Walsh, but that came to an end when Walsh died in April 1910. In 1911, still hoping to produce radium salts, Lockwood exchanged letters with Yale professor Bertram B. Boltwood, a well-known American expert on radium, asking if a reagent could be found to separate the radium from the barium. Boltwood replied that conventional chemical processing was not possible because barium and radium were in the same chemical family. Fractional crystallization, the same process used by the Curies, was necessary to separate out the radium. He encouraged Lockwood to continue his work and sell the radium to recover costs, but nothing further was done.[131]

To bring radium to Pittsburgh Joseph Flannery would have to go to Europe. He had travelled there before seeking knowledge about vanadium steel, now he went seeking radium. On January 10, 1910 Flannery, then General Manager of the AVC, accompanied by George E. Lees, AVC Advertising Manager, left for a five-week trip to England and the European continent.[132] Details of Flannery's European itinerary have not been found but can be inferred. European radium research was centered in England, France, Austria, and Germany. In England William Ramsey at University College in London, Ernest Rutherford at the University of Manchester, and Joseph John Thompson at the Cambridge Cavendish Laboratory would have been candidates for visits. Since he would later bring German scientist W. A. Schlesinger to his radium company, it is likely he visited the Kaiser Wilhelm Institute of Chemistry headed by Otto Hahn. Another scientist from the continent who was to come to his company was Austrian Otto Brill, so

Flannery probably visited the Institute for Radium Research in Vienna, headed by Stefan Meyer. He certainly visited Curie's laboratory in Paris.

But Flannery returned to America empty handed.[133] As he spent time with his dying sister Flannery considered what he learned in Europe and his options.[134] There was a European market for medical radium and a limited one America. Because of the Austrian embargo on its pitchblende the radium would have to come from American ore — carnotite — but only in Europe were there factories to process the ore and their capacity was limited. From Flannery's business perspective would it not make better sense to produce radium in America, export it to Europe to fill demand there, and create an American market for it? And, perhaps, accomplish this in time to save his sister?

The Flannery brothers had retained rights to carnotite mining properties in Colorado dating to their initial interest in the mineral as a source of vanadium.[135] On August 3, 1910 Joseph Flannery wrote to Boltwood asking him to test three vanadium ores for radioactivity. Flannery described the ores as a "sulfide, red oxide, and clay oxide." What Flannery described as a sulfide was likely patronite, the red oxide perhaps red calcium vanadate, and the clay oxide probably carnotite. Boltwood agreed to make the tests. The carnotite was, of course, radioactive. Flannery made up his mind. He withdrew from the AVC to organize a new business venture to produce radium in the U.S., a decision that shocked his business associates who expressed concern about the wisdom of it.[136] As 1910 drew to a close, representatives of Joseph Flannery arrived in Paradox Valley in southwestern Colorado to acquire carnotite mine properties.[137] Kenneth Hequembourg, named superintendent of the operations in the valley, established a temporary headquarters in a rented homesteader's shack in eastern Paradox Valley and, across the road, another rented homesteader's cabin provided shelter and laboratory space for two chemists, Thomas J. Gearing (Joseph Flannery's brother-in-law) and C. V. Badgley (figures 2.1 & 2.2).[138] In early 1911 following a visit to the valley (figure 2.3), Flannery returned to Pennsylvania where he acquired property in Canonsburg, south of Pittsburgh, to build a plant to extract the radium from carnotite.

Flannery had other matters to address as well. He had to create a new organization and infrastructure to mine carnotite and ship it to Pennsylvania, find scientists and engineers to develop the industrial chemical processes to extract the radium from carnotite and refine it, create a market for medical radium in America, and hire managers to oversee operations in Colorado and Pennsylvania. The Flannery brothers' experience in mining and shipping vanadium ore from a remote location, developing processes to extract the metal, and managing the organization had been an outstanding success. It would serve as a business model for producing radium. But Joseph Flannery was to find the transition from vanadium to radium manufacturer a difficult one.

* * *

Initially, Flannery privately financed purchases of the properties in Colorado and Pennsylvania. In early 1911, he chartered the Colorado Chemical Company under the laws of Colorado but then shifted financing to the Standard Chemical Company (SCC), a company organized under the laws of Delaware in March 1911.[139] The SCC was authorized to search for, mine, and mill ores and minerals and was capitalized at $200,000.[140] Company officers were Flannery as president, Hequembourg as vice president, S. H. Thompson, a Denver, Colorado attorney, as legal counsel, and Peter K. Flannery, treasurer; other board members were James J. Flannery and James C. Gray, a Pennsylvania attorney previously associated with the Flannery brothers.[141] With respect to the name Flannery may have intended to emulate the Rockefeller's Standard Oil Company in choosing "Standard" for the company's name.[142] He was to use it later for naming SCC subsidiaries. On July 2, 1912 Delaware received a filing increasing the SCC's capitalization to $500,000. SCC's authorized capitalization eventually reached $1,500,000 in the form of 15,000 shares having a par value of $100.

Flannery next turned his attention to finding scientists and engineers to develop a process for extracting radium from carnotite. He asked Narcisse Helouis, the French chemist at the AVC Vanadium Sanitarium, to take on this project and in late 1910 shipped twenty tons of ore to Cambridge Springs.[143] After Flannery acquired the Canonsburg property, ore shipments were redirected to Canonsburg and Helouis relocated there.[144] In May 1911, George Lees, now Flannery's advertising manager, sought consulting help from Boltwood; he agreed and was soon asked to recommend chemists for carrying out the research and development in Canonsburg to jumpstart the work.[145] Boltwood recommended Rowland Bosworth, a recent Yale graduate.[146] At the same time, Lees provided details about the equipment in Canonsburg and submitted for comment Helouis' proposal for processing carnotite ore.[147] Time was of the essence because Boltwood was leaving at the end of June for two months in Europe. During an intense one-week period in late June 1911 in New Haven, Connecticut, Boltwood and Bosworth worked out an extraction method for carnotite ore and estimates of costs.[148]

After Boltwood sailed for Europe in July 1911 Bosworth reported for work at Canonsburg. Within a week, Bosworth wrote to Boltwood describing the plant being built and expressing his doubt about the competence of Helouis and his French assistant Bonneau.[149] By August both were gone and Bosworth made plans to move ahead.[150] Boltwood appeared to have agreed to a long-term consultancy with Flannery and things seemed to be on course.[151] But in January 1912 Bosworth wrote a lengthy letter to his mentor describing personnel conflicts and technical problems at Canonsburg. Lees had been holding back funds which led Flannery to dismiss him in August 1911. In December 1911, Flannery brought in a new technical lead who lasted less than six weeks.[152] Bosworth opined Flannery was "no judge of men and no manager….who can never make the business succeed" and asked Boltwood for help finding a new job.[153] In the spring of 1913 he left.[154] For his part Flannery was no less frustrated and expanded his search for a qualified expert.[155]

The Canonsburg plant's fortunes turned after Otto Brill arrived in late 1912 (figure 2.4). Brill was born in 1881 in what is now the Czech Republic, attended a technical school in Vienna and universities in Göttingen and Berlin, received a Doctor of Engineering degree in 1904, worked in William Ramsey's laboratory in London, and had experience working in the Joachimsthal works in Austria, a resume that clearly fitted Flannery's needs.[156] But co-workers at Canonsburg considered him arrogant and unwilling to accept suggestions from others and one, Arthur Miller, described him as "Tarter and Splint in the Thumb." [157] Whatever his shortcomings in interpersonal relations, Brill provided the technical competence that was so badly needed.

Other arrivals helped firm up the organization and management of the Canonsburg plant. Warren F. Bleecker, a chemist and 1903 graduate of the University of Colorado, became superintendent of the plant. Louis F. Vogt (figure 2.5), a chemist with extensive experience in industrial chemical processing that complemented Brill's laboratory background, became plant manager.[158] Flannery also sought a chemist to assist Brill and in 1912, after much persuasion, Charles H. Viol (figure 2.6), a recent Ph.D. chemistry graduate from the University of Chicago, arrived. Another key addition was Glenn D. Kammer (figure 2.7), a chemist from the University of Pittsburgh.[159]

The completion of the Vanadium Building in the Oakland section of Pittsburgh enabled SCC to move its administration, sales, and company offices from downtown Pittsburgh and provided space for laboratories for radium refining and research. The Canonsburg plant became responsible for receiving and processing carnotite ore and performing the initial refining of the plant's product, a mixture of radium and barium chloride salts. The salt mixture was then transferred to the Vanadium Building where the refining was completed and radium sources were prepared and packaged.

By January 1913, experimental production of radium had reached 2.1 grams and SCC announced it would commence commercial production of radium on January 15, 1913.[160] As Flannery had foreseen, American demand for radium was limited in contrast to Europe but thanks to Brill's previous European associations numerous orders were received from abroad.[161] Those orders led Brill to undertake one more task essential to the commercial success of SCC — obtaining a source of radium the quantity of which had been measured and certified by a competent authority as a reference to calibrate and certify radium sources marketed by SCC.

In early January 1913 Brill wrote to Boltwood asking his assistance in calibration and certification.[162] Boltwood informed Brill that an International Radium Standards Committee had been formed to establish standards for radium measurements. Its members included among others, Marie Curie, Ernest Rutherford, Stefan Meyer, and Boltwood. Subsequently, Marie Curie prepared an international primary radium standard which had been placed in the Bureau International des Poids et Mesures in France. Secondary standards were being made for individual countries including the U.S. The U.S. standard would go to the National Bureau of Standards [NBS; today the National Institute of Standards and Technology (NIST)].[163] The committee agreed that the unit for radioactivity would be the "Curie" in honor of Pierre Curie. In December 1913, NBS received a radium standard from Marie Curie accompanied by a calibration certificate jointly signed by Marie Curie, Ernest Rutherford and Stefan Meyer. By spring 1914 NBS was calibrating radium sources.[164]

That was in the future. SCC needed a calibration source immediately because it had 500 mg of radium already sold to British hospitals whose sale was pending certification. On May 22, 1913 Brill left for Europe to personally deliver the radium but first stopped in Paris to have the radium assayed by Mme. Curie. He set aside and retained a one-milligram source that she assayed and took that source with him when he returned to the U.S.[165] It became SCC's calibration source, "a small dab" of radium bromide in a glass tube about 10-12 mm long assayed as 0.96 mg of the radium element by the co-discoverer of radium who also prepared the international standard.[166] In the absence of an American calibration standard for radium, Brill's gambit was "just-in-time" and cleverly done having gotten the British sources and a source for SCC certified by Marie Curie. By September 1913, SCC acquired two more standards, containing 5.83 and 19.24 mg of radium, that were prepared by the Radium Institute of the Imperial Academy of Sciences in Vienna Austria under the direction of physicist Stefan Meyer.[167]

Then, in 1913, the NBS ordered two sources from SCC and asked that its physicist Noah Ernest Dorsey be allowed to observe its calibration procedures; Dorsey spent four days in the SCC's radium laboratories.[168] SCC delivered the sources to the NBS in September 1913 accompanied by SCC Calibration Certificates nos. 28 & 29, signed by Leslie V. Walker, Chief Physicist, a graduate of Cornell University, and Charles H. Viol and counter-signed by Joseph M. Flannery (figure 2.8).[169]

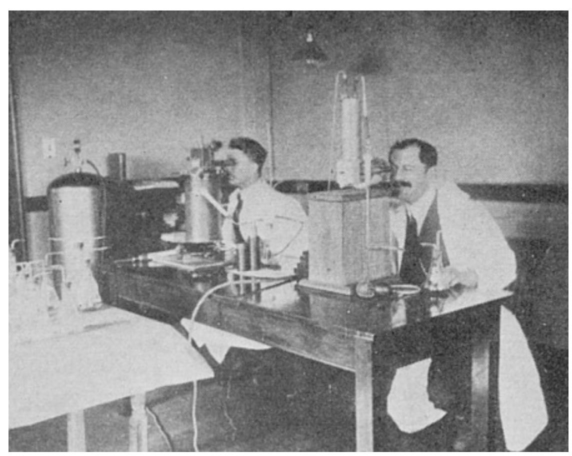
Until the NBS received the American radium standard from Vienna in December 1913, SCC's three radium sources served as de facto American calibration standards. In January and February 1914, when Congress held hearings on the federal role in the production of radium, Viol discussed the need for calibration standards, SCC's procedures for certifying the content of their sources, and the origins of SCC's three standards — which were displayed at the hearing. In response to a question about SCC's helping out NBS Viol answered:

> We have been more than happy, because we have wanted them to do it. I think it was our urgent insistence that pushed this matter along faster than it might normally have gone. The United States is the last of the big countries to have a radium standard available. England has such; Germany has such, France has such; Austria has such. Now, the United States has such, and measurements of quantities of radium can be accurately tested and certified to.[170]

In September 1913, Brill was recalled to Austria by the Austrian government. With the chemical process for extracting the radium from carnotite now established in Canonsburg and competently overseen by Vogt, Brill's departure was not a major concern there. But in Pittsburgh the refining of radium, preparation of radium sources and calibrating them, and developing a long-term research and development program for medical radium needed technical oversight. To fill this position, Flannery turned to Brill's assistant, Charles H. Viol.[171] Viol, 27 years old, was appointed director of the SCC radium laboratories, a position he was to admirably fill for the duration of SCC's operations.

After an admittedly rough start, Joseph Flannery proved to be a good manager and judge of men. For the first time, radium was commercially produced in the U.S. SCC had become a leader in promoting establishment of an American government standard for measurements of radium and Pittsburgh had become the American center for radium production and research.

2.1 Homesteader shacks served as the first SCC headquarters in Paradox Valley. Left, on the porch is Kenneth Hequembourg, SCC's first superintendent operations in Colorado. *HHC4* 2.2. Right, across the road, another rented homesteader's shack provided sleeping quarters and laboratory space for Thomas J. Gearing (shown), Joseph Flannery's brother-in-law, and C. V. Badgley, a chemist. *HHC4*



2.3 Left, May 1911, in Paradox Valley, left to right, Kenneth Hequembourg, Thomas. J. Gearing, Joseph Flannery, and S.H. Thompson. Thompson was the SCC attorney in Colorado for the first two years. *HHC4* 2.4 Right, Otto Brill, on the right, an Austrian chemist with a D.Sc. from the University of Vienna. *ACS2*

2.5 Left, Louis Fenn Vogt, superintendent of the SCC Canonsburg mill. *HHC3* 2.6 Center, Charles H. Viol graduated from Purdue University in 1907 and later received a Ph.D. in chemistry from the University of Chicago. *CCT* 2.7 Right, Glenn Donald Kammer, a University of Pittsburgh-trained chemist. *ACS1*

Radium Laboratories

Certificate No. 28

The Standard Chemical Company
Pittsburgh, Pa.

This is to Certify that 2.0 Milligrams of Radium Barium Sulphate containing 1.04 Milligrams of Radium Element, were prepared by the Standard Chemical Company and delivered to U.S. Bureau of Standards of Washington, D.C.
We absolutely guarantee the quantity of Radium Element contained in this preparation, measurements being based on the "Milligram of Radium Element" as defined by the International Radium Standard.
In Witness Whereof we hereby sign this Certificate this 5th day of Sept. A.D. 1913

Chief Physicist   Director

2.8 This early SCC radium calibration certificate, serial number 28, and dated September 5, 1913, was issued to the (U.S.) Bureau of Standards (now the (U.S.) National Institute of Standards and Technology). It was signed by Charles H. Viol, Director of the Radium Laboratories, and Lester V. Walker, Chief Physicist, and counter-signed by Joseph M. Flannery along the left edge. A vignette of the vanadium building and a corporate gold seal completed the certificate. *NIST*

Chapter 3: Paradox Valley

"Yellow stuff."

Paradox Valley in Montrose County in southwestern Colorado became the center of SCC's mining operations. The valley is 3 to 6 miles wide and 35 to 40 miles long running from the southeast to the northwest and ending at the La Sal Mountains in Utah (figure 3.1). Bisecting the valley is the Dolores River that paradoxically flows across it giving the valley its name. Above the north side of the valley the San Miguel River flows parallel to the valley until it joins the Dolores River.

When Europeans came to the area it was home to the Utes, a tribe that ranged across much of Colorado, northern New Mexico and Utah.[172] Around 1640, following their contact with the Spanish explorers, the Utes began to use horses greatly increasing their mobility. The increased mobility changed the organization of the tribe from small family units into larger units, bands. In Paradox Valley the Tabeguache or Uncompahgre band predominated. Following the end of the Mexican War in 1848 and the annexation by the U.S. of Mexican territories in the southwest, the Utes mainly occupied what became Colorado and Eastern Utah. The discovery of gold in 1858 near Denver changed this. Beginning in 1863, a series of treaties between the Utes and the American government had the effect of securing more land for settlers and decreasing land reserved for the tribe. The Treaty of 1880, among other things, had the effect of removing the last band of Utes from Colorado except for a reservation on the southwestern corner of the state for the Southern Utes. In June 1882, Congress opened six million acres of former Ute land to public settlement.

By then Utah and Colorado cattlemen were moving cattle herds into the valley for grazing and establishing ranches (figure 3.2). The San Miguel Cattle Company established one of the largest, Club Ranch. Cattle-raising and agriculture soon became the main valley activities. To reach eastern markets, cattle herds in the valley were driven to Montrose, the nearest railhead. In 1890, the narrow-gauge Rio Grande Southern railroad reached Placerville (figures 3.3 & 3.4) which then became the shipping point for valley cattle and agricultural products. In the western part of the valley, the town of Paradox became a trading center and in the eastern end of the valley Naturita and Nucla were established as communities.

The gold rush hit the valley in the 1870s when miners began panning placer deposits along the Dolores and San Miguel Rivers.[173] The most promising claims were at Mesa Creek Flats along the Dolores River four miles beyond its junction with the San Miguel River. The Montrose Placer Mining Company, a St. Louis company, purchased the claims with the intention of using hydraulic mining to unearth the gold. To provide an adequate supply of water for the operation San Miguel River water was diverted to the claims. The water was carried in a combination of earthen ditches, wooden flumes supported on wooden trestles, and in sections where neither of those was possible, in a wooden flume hung from the vertical rock walls of the San Miguel and Dolores River canyons. The last became famed as the "Hanging Flume" (figure 3.5). About 1,800,000 feet of lumber went into its construction. Completed in 1891, the system cost over $100,000 ($2,800,000 in 2018 dollars), an extraordinary amount of money — just to move water from one place to another. It carried 80 million gallons daily over a steady 0.17% downgrade for ten miles dropping a total of ninety feet. At its end a tank collected the water and provided the pressure head for the nozzle. This mining venture struggled to make a profit and in 1903 it closed after part of the flume failed. Afterwards, the earthen ditches disappeared as weathering and road construction took their toll. Salvagers, including from SCC, scavenged most of the wood components (figure 3.6). A few remnants of the Hanging Flume survive and a 48-foot section has been reconstructed to provide visitors an idea of the original structure (figure 3.7).[174] They serve as reminders of the importance of water in the southwest and the great lengths taken to access it.

The Paradox Valley gold rush was followed by the discovery around 1895 of copper ore in the western portion of the valley. The Cashin copper mine began operation in 1889, a copper extraction plant was built, and the town of Bedrock was established nearby. The extraction plant required coke for its operation, and to supply it a mine was opened near Naturita where a coal seam lay under the valley floor. Ovens were built to convert the coal to coke and the small community that developed there was named Coke Oven.

In 1881, Andrew J. Talbert, (or his brother; Thomas, accounts vary) sent samples of a yellow mineral from a claim on Roc Creek in Montrose County, Colorado to an assayer in Leadville who reported gold and traces of silver. Other assays were not so promising and the claims lapsed. The "yellow stuff" was well known to the Utes who used it as a pigment. Around 1897 or 1898, Gordon Kimball in Ouray, Colorado gave some of the mineral to French chemist Charles Poulot who had arrived in Colorado interested in finding rare metal ores, especially vanadium and uranium. Poulot realized it contained uranium and sent a sample to France for further analysis. Sorbonne chemists identified it as a previously unknown mineral consisting of a uranyl vanadate salt and named it carnotite in honor of Adolphe Carnot, a prominent French mineral analyst of the time.[175]

* * *

The carnotite mineral is a yellow, powdery substance. In Paradox Valley relatively pure carnotite was occasionally found in small clumps that miners called "logs," "trees," "bug holes," or "butterballs." More typically, carnotite occurred as coatings on the grains of sandstones (figure 3.8). The carnotite-bearing ore is part of a thin sandstone blanket atop the rims of Paradox Valley — "rimrocks." The ore occurs as isolated pockets rather than continuous veins. Under these circumstances tunneling is too expensive to locate the pockets. Instead, exploratory drilling into the rimrocks was used. By 1921, SCC had drilled and mapped 6,000 exploratory holes in and around Paradox Valley and in eastern Utah.[176]

Open cuts and tunnels were used to mine shallow ore deposits (figures3.9 & 3.10).[177] To reach deeper deposits inclined shafts were dug from above. The ore was brought to the surface in cars pulled up inclined railways by cables (figure 3.11).

Pure carnotite consists of 55% uranium. However, uranium concentrations are cited in terms of its oxide, U_3O_8. ("U-three-O-eight"). The corresponding concentration in pure carnotite is 65% U_3O_8. Carnotite ore concentrations of U_3O_8 are much less, ranging from a fraction of 1% to a few percent. When SCC began commercial operation most ore purchasing agents declined to handle less than 2% ore. [178] The criteria for ore sent to the SCC plant in Canonsburg was 2%.[179]

However, the U. S. Bureau of Mines (USBM) pointed out that in meeting the market criterion of 2% ore there was a great loss in hand-sorting the ore and it was wasteful to leave the lower grade ore unused.[180] To conserve this resource the USBM recommended concentrating these lower grade ores to reduce waste adding that the extra cost could be offset by the higher price commanded by the higher-grade concentrate.[181] The USBM saw concentrating ore, a.k.a. milling, as a means to minimize waste but for SCC milling ore was a necessity for ensuring long-term delivery of ore to Canonsburg meeting its 2% criterion. [182]

The ore was visually sorted by experienced miners in well-lit areas outside the mine, usually in tented areas (figure 3.12) or during the winter in heated sheds.[183] The visual criteria for sorting were based upon laboratory measurements of the radioactivity of ore samples from the mine. Ore was sorted into four categories: waste rock; sub-grade ore, usually less than 0.5%, that was set aside for possible future use; ore destined for milling, usually 1%; and shipping ore, usually 2%, sent directly to Canonsburg although over time as higher-grade ore became scarce 1% shipping ore was sent directly to Canonsburg.[184]

Shipping ore was packed into sacks, weighing about 75 pounds each, and carried by burros down narrow trails to centrally located weighing stations, loaded onto wagons, and taken directly to the Placerville railroad station by contract freighters (figures 3.13 & 3.14). There the sacks were loaded in narrow gauge boxcars (figure 3.15) that were taken to Salida Colorado where they were transferred to standard gauge boxcars for delivery to Canonsburg.[185]

SCC constructed its mill at Ford Camp on the south side of the San Miguel River west of its junction with Hieroglyphic Canyon (figure 3.16). At this point, the river was shallow enough for horses and wagons to cross from the 65-mile stagecoach road from Placerville. Although it was a remote location, it had the advantages of direct access to the stagecoach road, ready access to water, and was centrally located relative to the mining camps scattered in and around the valley. John I. Mullen, a Notre Dame trained civil engineer, was tasked with building the mill. (figure 3.17).[186] His first project was constructing a bridge to replace the crossing ford which had been difficult to use at best (figure 3.18) and was impassable during floods. Built using locally available timber and recycled mining cables (figure 3.19) his bridge handled every load that traversed it and survived every flood that flowed beneath it. Another necessary improvement was re-grading and paving the stagecoach road. This allowed four-wheel drive trucks, nicknamed "Quads," to replace the four- and six-horse teams that hauled freight wagons (figure 3.20). [187] Although SCC maintained a fleet of Quads, the company found it cheaper to contract with local freighters keeping its own fleet in reserve.[188]

The milling machinery was powered by electricity from a hydroelectric plant using water diverted from the San Miguel River. The water was carried in a ditch system beginning near the river's junction with Hieroglyphic Canyon (figure 3.21) and continued west to the powerhouse. The inlet for the SCC ditch was across the river from the beginning of the older ditch and flume system built to deliver river water to the placer gold mining operation. Like it, the SCC ditch system was a complex one.

Immediately east of the ditch inlet, its path crossed that of storm water draining from Hieroglyphic Canyon to the San Miguel River. To avoid erosion of the ditch by the canyon's drainage a short, wide wooden overhead spillway was built to carry the storm water over the ditch (figure 3.22). Further west porous rocky ground unsuitable for carrying water was encountered so a wooden flume was built to convey the water over this zone. Wood gates at the ditch inlets controlled the flow into the ditch. This massive earth-moving project was completed using only animal power and human tools and ingenuity. The ditch ended at the powerhouse where a water turbine powered a 200-volt, three-phase alternating current generator supplied by Pittsburgh's Westinghouse Electric Company (figure 3.23). In the fall of 1914, Mullen and Albert D. Riley, a mechanical engineer from the University of Pittsburgh who designed the power plant, opened the inlet gates letting the first water into the ditch for the first time to power the generator (figures 3.24 & 3.25).[189]

Operating the mill proved problematic. Arthur L. Miller, a 1914 Purdue graduate chemist who joined SCC in 1914 and served in a variety of positions at SCC (figure 3.26), began his career at the mill. He found that the hydroelectric plant was a challenge to run even when there was adequate water from the San Miguel River. When river water was low, a four-cylinder automobile engine was connected to the generators. In addition to babying the engine, Miller had to ensure the Westinghouse AC generators were synchronized: "[P]roducing power the hard way," he described it.[190]

Milling did not involve chemical treatment of the ore. Instead mechanical means were used to separate the waste rock from the carnotite-bearing material by taking advantage of the differences in weights of the components. Initially, this was done by pulverizing and drying the ore and then using industrial air cyclones to gravimetrically separate the waste rock and ore-bearing material. It proved to be an inefficient process. Given this and the difficulty in operating the water-powered electrical generating system SCC elected to replace it with a wet process.[191] Since water was now needed for milling two Fairbanks-Morse diesel engines were installed to power the electrical generating system (figure 3.27).[192] To supply fuel for the engines SCC maintained a fleet of privately owned narrow-gauge railroad cars to ship diesel oil from Montrose to Placerville where it was transferred to tanker trucks (figure 3.28).[193]

The wet mill process was a success, its concentrates averaging 3.5 to 4% U_3O_8.[194] As a result, the mix of ore shipped directly to the Canonsburg plant and the concentrates from the mill always met its 2% criterion.

* * *

There was much more to the mill. Its workforce numbered about 30 men. The nearest towns, Nucla and Naturita, were more than 15 miles away and the road to them was poor. Montrose County was dry (i.e., no alcohol allowed) and there was little for workers to do in their spare time. Accordingly, workers, most of who were single, preferred to work seven days a week.[195] A two-story boarding house was built to house them (figure 3.29). Over time married workers joined the workforce and their wives and children joined them creating a need for a school. It was housed in a semi-permanent tent building, served six to ten students, and in 1917 Mullen convinced Montrose County to provide a teacher (3.30).[196]

In 1913, Hequembourg was forced to resign from the SCC board for undisclosed reasons and sell back his stock to SCC.[197] Flannery placed Mullen in charge of the SCC operations in the valley. Mullen became a legend for his hard work, direct action, and extraordinary kindness to his men.[198] When the U.S. Post Office approved a post office for the site Flannery intended to name it "Mullen" but his letter passed through Mullen's hands before mailing. Mullen drew a line through his name and changed it to "Joe Jr." naming it after Flannery's oldest son.[199]

The five-acre Joe Jr. complex was an impressive sight. Most prominent was the mill, a multi-story building that sat against the hill behind it. In front were the boarding house and the ditch system. Other features were buildings housing the diesel generators, boilers, compressors, and laboratories, corrals, a commissary, gardens for the commissary, and semi-permanent tent buildings (figure 3.31).[200]

* * *

SCC mining operations extended to adjacent San Miguel County and eastern Utah but the majority of mining camps were centered in and near the valley.[201] Mining camps that became well known for their high productivity included Club Camp (a.k.a. Club Ranch), Ford Camp, Dolores Camp, and Julian, Shamrock, and Long Park mine groups, all on the north side of the valley, and Thunderbolt, Joe Dandy, Monogram and Wild Steer Canyon mines on the valley's south side. Club Camp was the largest having several permanent buildings to house workers and equipment and enjoyed electrical service. Other camps used semi-permanent tents to shelter workers and equipment.

To support the Joe Jr. mill and mining camps SCC established its valley headquarters in Coke Oven. It purchased the Coke Oven Ranch and built office buildings, a laboratory, commissary, warehouse, stock corrals, truck garage, housing for the superintendent and his family and living quarters for workers, and established telephone connections.[202] In addition to mining supplies, logistical support for the camps included food for the men, feed for burros and horses, and most importantly — in this semi-arid country — water. Trails to the camps were poor so everything needed at the camps had to hauled in on the backs of burros. In the case of water each burro carried two ten-gallon cans. At the camps the most important persons were the cooks. Years later their names were still remembered by former miners.[203]

Coke Oven workers and their families provided their own entertainment. Many of the couples were newly-weds and got together for card games and, at homes with a piano, for sing-alongs.[204] Typical of the couples were John and Margaret Galley. John Galley was born in Scottsdale, Pennsylvania (figure 3.32). His parents moved to McKeesport where Galley attended Carnegie Tech studying civil engineering. He left before getting his degree to work in Utah. In 1915 he joined SCC and worked a variety of positions becoming chief clerk and assistant to Mullen. Margaret came from Nucla. She and Galley were married in 1919 and moved into one of the original houses in Coke Oven, the “rock house.” Since it had a piano and fireplace it was a popular gathering place. For a number of years, Margaret Galley tutored Mullen’s children.

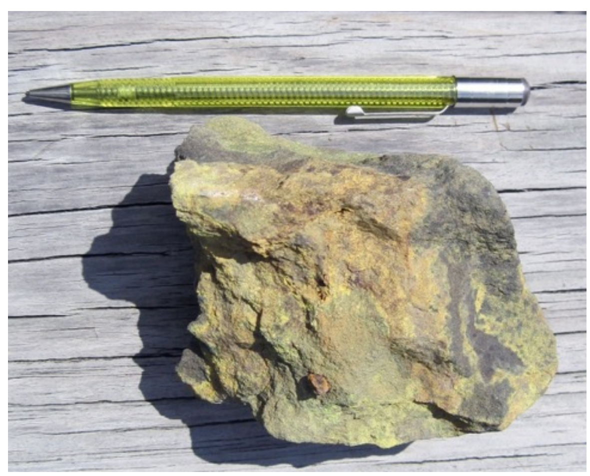
During warm weather, there were picnic outings and baseball games. Company sponsored picnics were held in Nucla. When September arrived many traveled to Montrose for the annual county fair that included a rodeo (figure 3.33).[205] Winter provided opportunity for sleigh rides (figure 3.34). For the Christmas season Mullen made sure that the men at the mining camps, no matter how isolated, got their traditional feast.[206] Life in Coke Oven was sometimes rough but the Galleys in looking back also remembered good friends and times of fun.

By January 1914 Flannery had spent $135,000 ($3,380,000 in 2018 dollars) in Paradox Valley to purchase its mines, build the mining camps, the mill and other buildings, improve the roads, and pay wages.[207] Building the mill alone cost $50,000 ($1,250,000 in 2018 dollars).[208] SCC employed between 125 and 275 workers in the valley, their number varying seasonally and over the years as the market for radium fluctuated (figure 3.35).[209] They and their families became part of the communities in Coke Oven, Joe Jr., Nulca, and Naturita. For western Montrose County, SCC had become an important economic engine.

3.1 A November 2000 midday aerial view of Paradox Valley Colorado looking northwest towards Utah and the La Sal mountains. Midway, the Dolores River paradoxically crosses through gaps in the valley sides. *WPI*

3.2 Left, cattle-ranching was a major enterprise in Paradox Valley. *ORAU* 3.3 Right, a Rio Grande Southern Railroad Company stock certificate. *JOL*

3.4 Left, the Rio Grande Southern Railroad Company railroad station in Placerville was the second busiest cattle station in Colorado. *ORAU* 3.5 Center, the hanging flume in operation doing what flumes do — channeling water. *IAWC* 3.6 Right, an SCC team salvaging timber from the abandoned flume. *RHS*



3.7 Left a reconstructed portion of the Hanging Flume. *IAWC* 3.8 Right, a carnotite ore specimen from Paradox Valley. *JOL*

3.9 Left, in the Last Chance claim of the Dolores group, the ore was near enough to the surface to enable open-cut mining, 1914. *HHC4* 3.10 Right, the Thunderbolt mine claim in 1911. Three mine shafts are visible. *HHC4*

3.11 Left, headhouse of the inclined mine shaft #2 at Club Camp. An ore car is on the incline; another is at the rear being unloaded. *HHC4* 3.12 Right, the ore was sorted inside the tent. Ore destined for the mill went to the ore bin on the right for loading into wagons. Higher-grade ore was separated and bagged for shipment to the Placerville railhead. Waste rock was discarded to the sides. *HHC4*

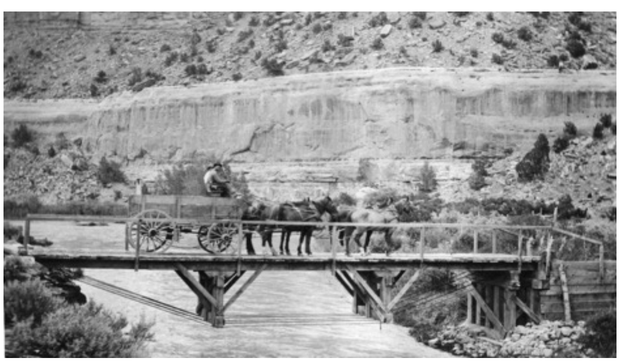
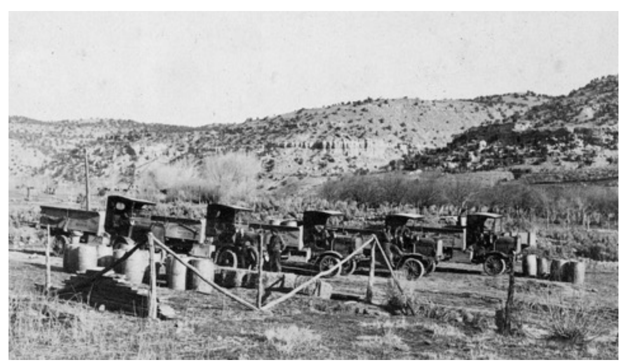
 

3.13 Left, burros carrying the ore down a mountain trail to weighing stations. *ORAU* 3.14 Right, contract freighters hauled the ore to the Placerville railroad station over an old stagecoach road. This is one of the better-graded sections. *HHC4*

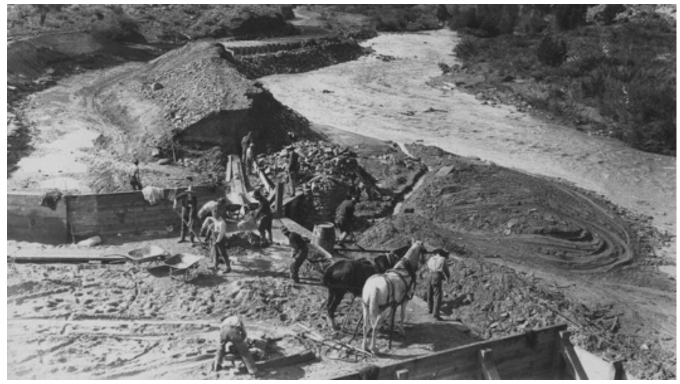
3.15 Ore sacks at Placerville awaiting loading into the boxcars. *ORAU*

3.16 An early photograph of the SCC Joe Jr. mill site (and later Uravan). The view is looking south across the San Miguel River toward the end of Hieroglyphic Canyon — the notch in the hillside left of center in the upper half of the picture. The mill complex was built on the flatland between the canyon notch and the ranch on the right. *ORAU*

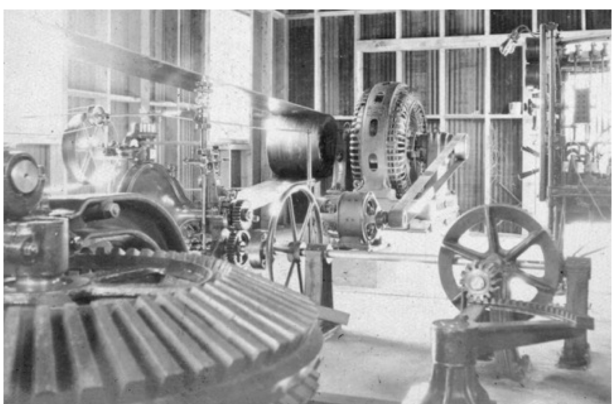

3.17 Left, John I. Mullin succeeded Kenneth Hequemburg as superintendent of SCC's Colorado operations and supervised construction of the mill. *RHS* 3.18 Right, the Joe Jr. site was near Ford Camp, a shipping center for ore from the mines, but on the other side of the river. It was crossed by way of a ford giving the site its name. *HHC4*

3.19 Left, Mullin's bridge rested on raised river banks to minimize damage to the bridge from debris carried by river floods. *RHS* 3.20 Right, after the stagecoach road was re-graded and paved, four-wheel drive trucks ("Quads") did the hauling. This fleet belonged to SCC. *HHC4*



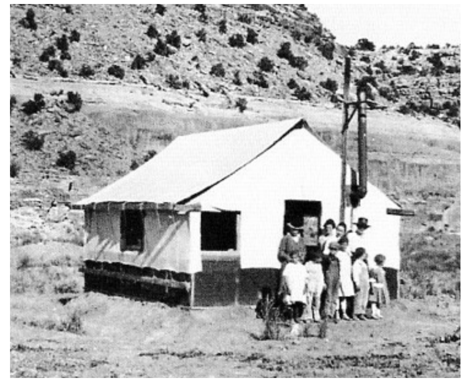
3.21 Left, construction of the Joe Jr. mill in 1914 included digging a ditch to divert San Miguel River water to the mill powerhouse. *HHC4*   3.22 Right, a view of the ditch looking downstream. In the foreground is the short spillway to carry Hieroglyphic Canyon storm water over the ditch. The San Miguel River is on the right and the horses face the direction of the flow of the canyon drainage. *HHC4*



3.23 Left, the interior of the powerhouse. In the left foreground is the horizontal bevel gear that transfers power from the water turbine wheel (below the power house) to a matching bevel gear (out of the picture on the left) and the belt that drives the electrical generator. *HHC4*   3.24 Right, on October 15, 1914, John Mullin, left, and Albert D. Riley, center, opened the inlet gates to let the first water into the ditch. *RHS*

3.25 Left, Albert D. Riley, a mechanical engineer, had a major role in designing the mill and left extensive written records and high-quality photographs of SCC's operations in Paradox Valley. Shown at his drafting table in Paradox Valley in November 1914, he presents a classic image of an early 20th century engineer at work at his drafting table and drafting tools and a folding ruler tucked into his back pocket. On the ledge is his folding camera, bottles of ink, and the cover of the August 29, 1914 *The Saturday Evening Post* that featured a portrait of an attractive young woman. *HHC3* 3.26 Right, Arthur L. Miller, a chemistry graduate of Purdue University, joined SCC in 1914 at the Joe Jr. mill and was later employed in the SCC laboratories in Pittsburgh. The photograph was taken in 1939, ten years after he left SCC. *PPG*

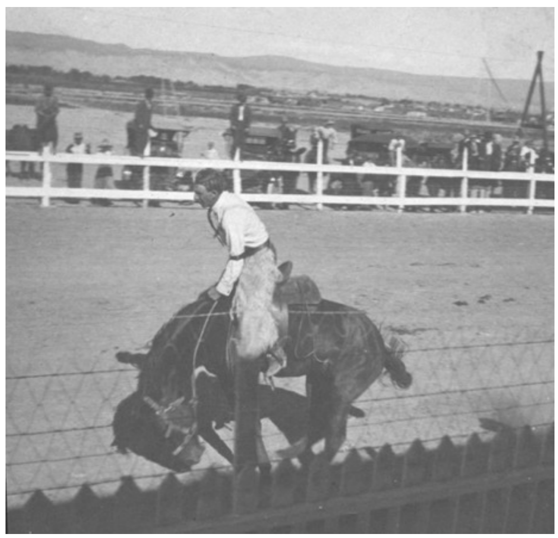
3.27 Left, the Fairbanks-Morse diesel engines to power the generators are up and running. Later, the engines were enclosed in a building. *RHS* 3.28 Right, SCC reserved a fleet of narrow-gauge railroad tank cars to deliver the diesel oil to Placerville. From Placerville, trucks hauled the oil to the Joe Jr. site. *RHS*



3.29 Left, the Joe Jr. boarding house. The building in the back is the mill, see Figure 3.31, below. *HHC4* 3.30 Right, the first school was in a tent building. *RHS*

3.31 The Joe Jr. mill after it was expanded and diesel engines, housed in the small building, center left, replaced the water turbine to power the electric generators. The large building, center top, is the mill. In front, the boarding house, garden plots, auxiliary buildings, and the ditch that now carried water pumped to the mill for processing the ore. *HHC4*

3.32 John Galley at work. *RHS*



3.33 Summer fun – visiting the Montrose County Fair in Montrose and watching a bronco bucking contestant. *HHC4*

3.34 Winter fun – Mrs. John Mullin and daughter Irene ready to take a sleigh ride. *RHS*

3.35 In 1921, the Joe Jr. mill workforce assembled in front of the boarding house for a group portrait. W.W. Gaw, mill supervisor, is in the top row, second from the left, leaning against the post. *HHC4*

Chapter 4: Canonsburg
"Now hold your hat!"

The Joe Jr. mill was a challenge to build and operate. Machinery and supplies had to be hauled long distances over poor roads to construct it. Water, a scarce commodity, had to be diverted for it. Diesel fuel was needed as well. The next step was to treat the ore to extract the radium. Extracting radium from carnotite ore required a larger, more complex plant needing large amounts of amounts of chemicals, water, and fuel and ready access to a pool of skilled workers experienced in operating industrial-scale mechanical and chemical equipment. These factors made extraction of radium an impracticable proposition in the remote Paradox Valley.[210]

Flannery turned his attention to the Chartiers Valley in Washington County, south of Pittsburgh, where the brothers operated their bolt factory and AVC plant. Besides his familiarity with the valley, Flannery had another reason for considering the valley as a site for the radium production plant. The vanadium in the carnotite ore would be a valuable byproduct, and the brothers' AVC plant in Bridgeville was an obvious prospective customer. Flannery found a suitable property nearby in North Strabane Township adjacent to the Borough of Canonsburg in Washington County, about 19 miles south of Pittsburgh.

Washington County was created in 1781 when the Pennsylvania General Assembly carved it out of Westmoreland County. John Canon was one of the valley's first settlers and, in 1787, he laid the first plat for Canonsburg locating it on the stage road connecting Washington, Pennsylvania with Pittsburgh.[211] In 1871, the Chartiers Railway Company (later the Pennsylvania Railroad's Chartiers branch) (figure 4.1) was completed, providing direct service from Washington through Canonsburg to Pittsburgh and a rail link between the SCC and AVC plants.[212] Canonsburg was also served by the Pittsburgh Railways Company's interurban line from Washington to Pittsburgh. The town had sewer, water, and gas lines and electric and telephone service was available. Canonsburg's labor force was employed in coal mining and a variety of manufacturing enterprises, including manufacture of iron and steel products, tin plate, stoves, pottery, and china.[213] The Canonsburg had all the advantages that were absent in Paradox Valley.

The property that Flannery bought was originally part of a farm owned by the local Alexander family.[214] It was sold in 1901 to the Simpson Stove and Manufacturing Company.[215] In 1904 the stove works closed and the property mortgage went into default. When purchased by the SCC, the stove works consisted of only a single building but it was served by a railroad siding (figure 4.2). SCC enlarged the works to provide ore storage and house ore processing equipment, laboratories, and offices (figures 4.3-4.8). Large open vats built outside the buildings stored process solutions. Ore processing equipment included grinding units, acid-resistant pipes and tanks, and filter presses. Building the plant cost $125,000 ($3,360,000 in 2018 dollars).[216]

Management of the plant became the responsibility of Louis F. Vogt who joined SCC in 1913. Vogt attended Case Western Reserve School of Applied Science 1898-1899 in Cleveland, Ohio, but did not graduate. In 1901, he settled in Barberton, Ohio, near Akron, working as a chemist for a company making soda ash for glass making. In 1908 or 1909, he moved to Wilkinsburg, Pennsylvania working for the Vanadium Mines Company (VMC) which operated a vanadium ore mill in Cutter, New Mexico (now a ghost town) and a vanadium production works in Rankin, Pennsylvania. His experience in vanadium production may have led to his connecting with Flannery and his diverse hands-on experience in industrial chemistry made him an excellent choice to run the SCC plant.[217]

* * *

Although many patents were issued for processing ores to extract radium and other products, the specific extraction process used by commercial radium producers were generally considered to be trade secrets and not readily disclosed.[218] SCC was no exception, but after SCC discontinued production of radium, its process was disclosed by Viol.[219]

The level of radium in the carnotite ore was extraordinarily low, about eight to eleven parts per billion. To ensure this minute amount is extracted, barium, a member of the same elemental family as radium, is used as a "carrier." It is added to the ore and concentrates to a level that conventional chemical techniques can detect, "a tangible something to work with as compared to the eight to eleven part per billion of radium."[220] In Canonsburg, production of radium from the ore was indirect — extraction by subtraction. A series of chemical treatments systematically removed all the other constituents leaving as the final product a residue of barium and radium chloride. Enormous quantities of raw materials were needed. To produce one gram of radium required about 500 tons of ore, 500 tons of chemicals, 10,000 tons of distilled water, and 1,000 tons of coal.

The barium and radium chloride residue contained a very small quantity of radium chloride in a very large quantity of barium chloride, roughly one gram of radium in every one-thousand pounds of barium chloride. Barium had carried radium along in the treatment of ore because the two elements are in the same elemental chemical family and therefore behaved chemically in a similar manner. But that characteristic also meant chemical reagents could not separate them. The separation method selected was fractional crystallization, the same process used by Marie Curie. Heating a solution of the radium-barium chlorides will cause the water to evaporate which increases the concentration of the chlorides. Eventually, the solution became saturated and the chlorides began to precipitate, forming crystals. Radium chloride is incrementally less soluble than barium chloride. Because of this, the concentration of radium chloride in the crystals is slightly greater than the barium chloride. After the mother liquor is poured off the crystals are re-dissolved and the process repeated until the desired purity of radium relative to barium is obtained. It is a time-consuming, tedious process.

The initial fractional crystallization step took place in Canonsburg, but the remaining fractional crystallization took place in the SCC's radium laboratories in the Vanadium Building in Pittsburgh, so the mixed barium-radium crystals were sent there. Arthur Miller, the Purdue University chemist who joined SCC in 1914, described how it was done:

> The [dried radium-barium chloride salts] were then placed in large-mouth glass bottles, corked, put into suitable galvanized steel cans, with hinged locking top and carrying bail

[handle]. Now hold your hat! Tommie and his helper, with a can in each hand brought them to the Pittsburgh lab on the trolley! Probably a couple hundred mg radium."[221]

"Tommie" was Tommie Thompson, head of Department 8, the department where the initial fractional crystallization was carried out. The trolley was a Pittsburgh Railways Company's electric interurban car that ran from Washington, Pennsylvania past the plant to Pittsburgh (figure 4.9). After arriving in downtown Pittsburgh, they transferred to a Forbes Avenue trolley to ride to the Vanadium Building.

Thompson and his helper were exposed to radiation each time they did this. Their annual radiation doses were a function of the yearly amount of radium sent to Pittsburgh, the time spent riding the trolleys, and the radiation dose rate from the radium in the cans. Thanks to availability of PRC timetables archived by the Pennsylvania Trolley Museum the lengths of time they spent on the trolleys on each trip to Pittsburgh are known.[222] The dose rates to which Thompson and his helper were exposed depended on where the cans were relative to where they sat, and whether the cans were shielded. Absent information to the contrary, the cans were probably unshielded. Trolleys similar to those used during period SCC was using them have been preserved at the museum. Examining their seating arrangements provided a basis for estimating the positions of the cans relative to the riders, and from that, calculating the dose rate from each milligram of radium in the cans. The precise quantity of radium carried each trip is not a factor for determining the riders' annual dose, rather the deciding factor is the total number of grams of radium carried from Canonsburg to Pittsburgh in a year. Small quantities of radium taken each trip meant lower dose rates each trip, but more trips were necessary to deliver the radium. Conversely, larger quantities taken each trip meant greater dose rates but fewer trips. SCC's peak year was 1920 when 18.5 grams of radium was produced. In that year, Thompson and his helper would have received an annual dose of about 1 Sievert from this task. At the time there were no radiation protection standards in effect, but for comparison, 1 Sievert is twenty times the current U.S. Nuclear Regulatory Commission annual dose limit for a radiation worker of 0.05 Sievert.[223]

Vogt described the Canonsburg plant's process as one of the most complex and costly treatments of ore.[224] The equipment had to be frequently replaced because of damage by the chemicals used in the process. Incoming raw materials had to meet exact preset standards. Each month, thousands of laboratory tests were carried out to monitor production steps. Constant, careful supervision and adjustments of the equipment were needed to meet production criteria. Each of the plant's departments was staffed with workers trained in the specific operations of that department. Overall, about 150 workers were employed in Canonsburg.[225] The plant's success in extracting radium from the carnotite ore testified to the excellence of the industrial-scaled chemical process designed by Otto Brill and Charles Viol, Louis Vogt's hands-on management of the plant and the plant's highly skilled, dedicated workforce. The plant's success also validated Flannery's decision to locate it in southwestern Pennsylvania.


SHARES $50 EACH

No. 928

3 Shares.

THE CHARTIERS RAILWAY COMPANY

INCORPORATED UNDER THE LAWS OF PENNSYLVANIA.

Cancelled

This is to Certify, that Lizzie Brooks is entitled to Three Shares of the Capital Stock of The Chartiers Railway Company Transferable only on the Books of the said Company in person or by Attorney, upon surrender of this Certificate.

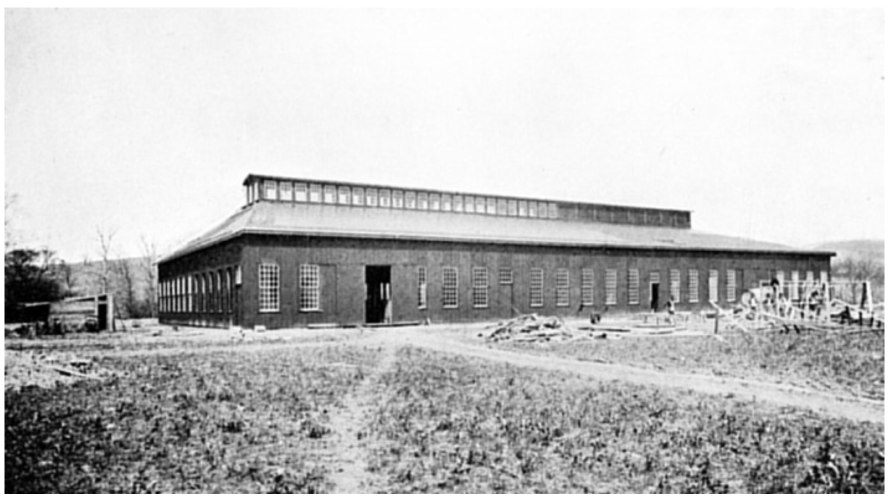
Witness the seal of the Company and the signatures of the President, Secretary and Treasurer, at Philadelphia, Pa. this 7th day of October A.D. 1884

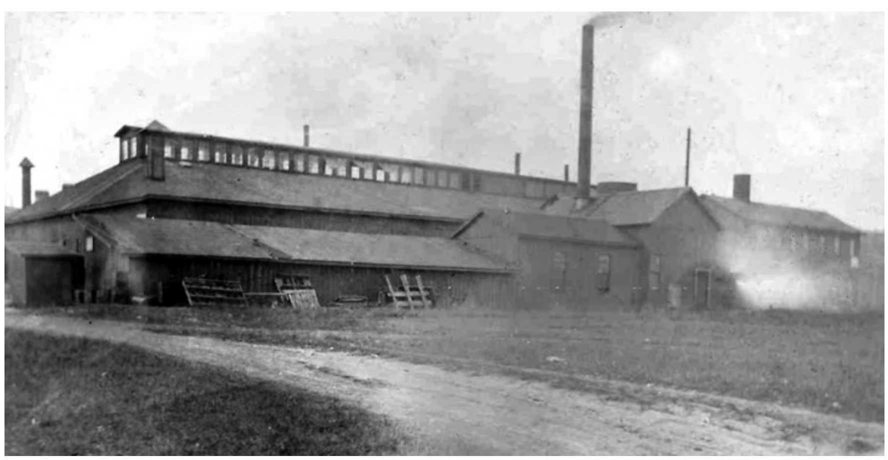
Treasurer

Secretary

President.

4.1 An 1884 stock certificate for The Chartiers Railway. *JOL*



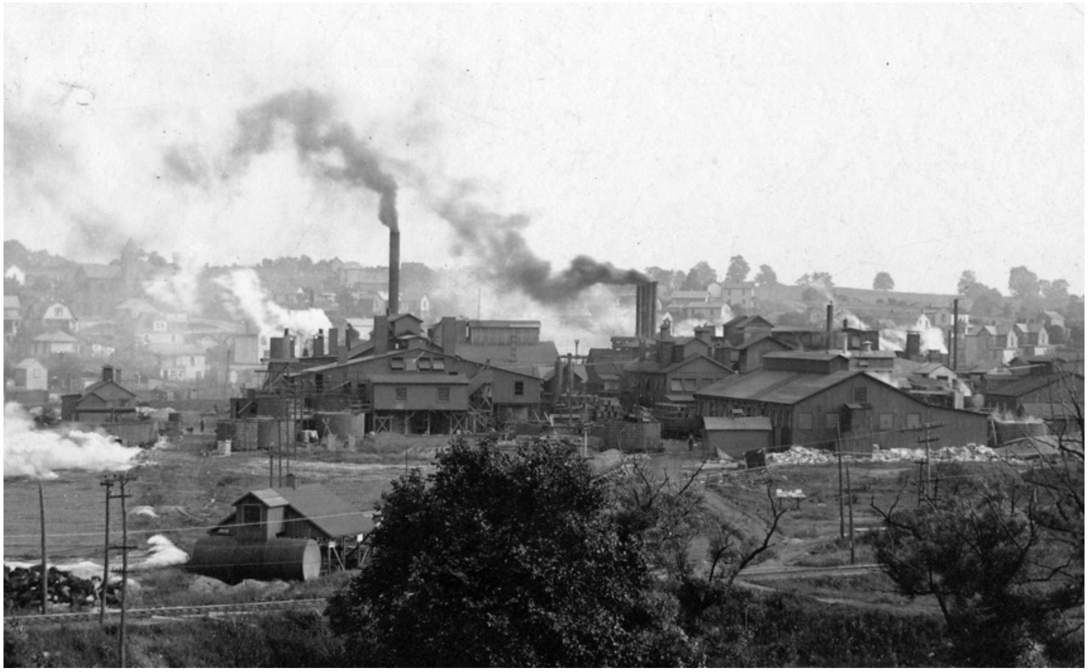


4.2 Top, Joseph Flannery purchased this former stove factory building in Canonsburg to house the ore processing plant. *JTH* 4.3 Above, by 1913, extensive modifications and additions had been made. The railroad siding that serviced building was on the far side. *ORAU*

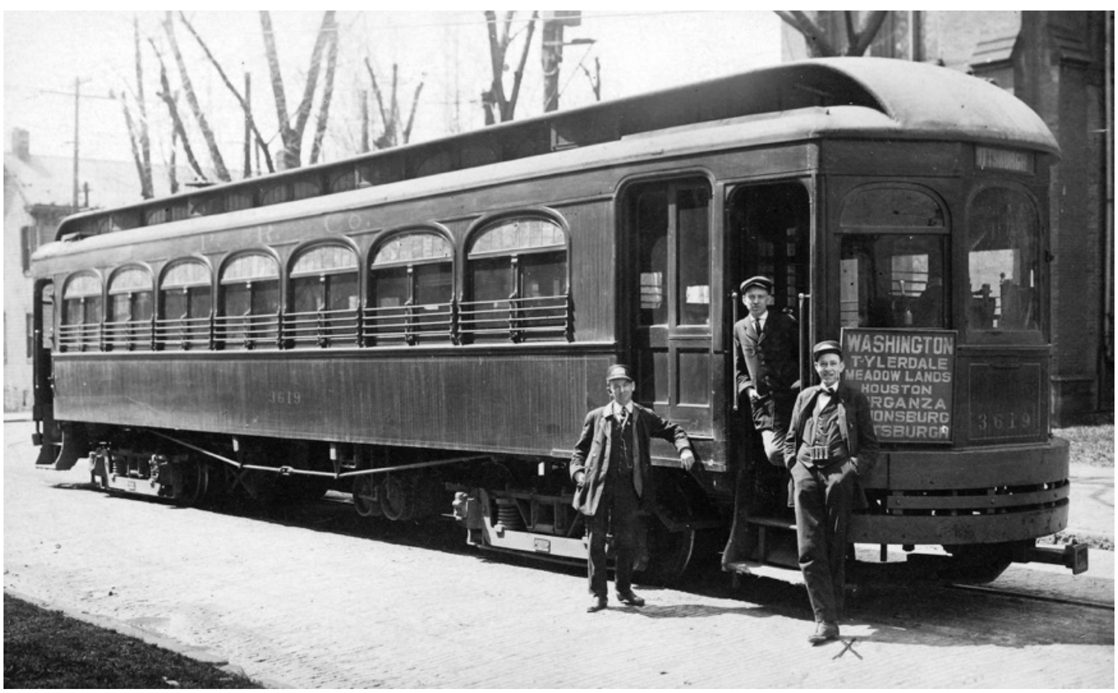
4.4 A 1913 view looking northward along the railroad siding. Boxcars loaded with sacks of ore and concentrate were delivered here along with shipments of chemicals, coal, and purified water. The signs warn against trespassing. *ORAU*

4.5, 4.6 Inside the plant — the ore storage area and part of the laboratory. *ORAU*

4.7 The office. Nothing fancy here — just the essentials — a safe, washbasin and mirror, and telephone and telephone book; other furnishings inluded a typist's desk, chair, and lamp, a bookkeeper's table and stool; and a horseshoe over the doorway with the open end facing up to fill with good luck. *ORAU*



4.8 A 1921 view of the Canonsburg mill complex seen from the north. In the foreground is the right-of-way of the Pittsburgh Railways interurban line from Washington, Pennsylvania to Pittsburgh. *JTH*



4.9 The dried radium-barium chloride salts were packed into glass bottles, corked, and carried in metal pails by messengers to the nearby trolley stop where they boarded a Pittsburgh Railways Company interurban car, such as this one, to Pittsburgh. *PTM*

Chapter 5: Pittsburgh
"A radical innovation."

The Vanadium Building was home to many of the Flannery brothers' business enterprises. The Oakland Savings and Trust Company, a Flannery enterprise headed by James Flannery, occupied the first floor of the Building. The second and third floors housed the administrative and marketing offices of the AVC and SCC (figures 5.1 & 5.2). SCC's laboratories and medical clinic were located in the top two floors (figures 5.3-5.5). The building was SCC's nerve center.

*   *   *

The fractional crystallization refining process begun in Canonsburg was completed in the top floor of the building (figures 5.6 & 5.7).[226] There, the radium-barium chloride salts from Canonsburg were re-dissolved and converted to bromides, a chemical form whose crystallization provided a greater degree of separation of radium from barium.[227] The salt solutions were poured into round-bottom porcelain dishes. Each dish was set on an asbestos sheet having a circular cutout to hold it over a gas burner to heat the solution to its saturation concentration at which point the salt crystals began to form. The mother liquor was poured off and recycled to recover the remaining radium and the radium-enriched crystals were re-dissolved. One could visibly follow the progression of the process because as the concentration of radium increased, the porcelain dishes diminished in size. At the end, the solution was transferred to a pure silica beaker (figure 5.8) and heated to evaporate the solvent. This work took place under a canopy hood and fan that exhausted the heat, acid fumes, and radon, the gaseous radioactive decay product of radium. Including its beginning in Canonsburg, the fractional crystallization process took seven to eight weeks to complete and the entire process to produce radium — mining, concentration, shipping, chemical treatment, and fractional crystallization required a minimum of six months.[228] Remembering that production of one gram of radium required about 500 tons of ore, SCC was extracting one gram of radium from *half a billion* grams of ore.[229]

Radium for medical use was usually concentrated to a radium-barium ratio of one-to-one (i.e., 50% radium). Higher purity salts were available by request and additional cost.[230] Sealed radium sources were made by encapsulating the radium salt — which was always in the form of powder — in glass tubes. Glass is an inherently fragile material and prolonged exposure to radiation from the radium increased its brittleness. The radiation also caused static charges to build up in the glass. Touching such a glass capsule could cause an electric spark that shattered the glass. Changes in temperature also stressed the glass, increasing the risk of its fracture. Another concern was buildup of gases inside the capsule. Radon, the decay product of radium, was a noble gas. Its volume relative to the radium salt was small, a mere 0.62 cubic millimeters, and did not normally cause overpressure problems.[231] However, if the radium salt was not completely dried, the radiation would decompose the water molecules ("radiolysis") to gaseous hydrogen and oxygen the volumes of which greatly increased internal pressure which, in turn, stressed the glass. Moreover, the mixture of hydrogen and oxygen gasses was potentially explosive. The consequences of an electric static spark, needless to say, could be disastrous.[232]

A classic example of a radium source explosion was reported in 1906 by the early American radium therapist, Robert Abbe.[233] He had obtained 50 milligrams of radium bromide which he sealed in a glass capsule. He always handled it using forceps. One day, when attempting to remove it from a silver tube, it instantly exploded when Abbe gently touched it with metal forceps. The glass capsule was shattered into many small fragments. While most of the radium bromide powder was contained inside the silver tube Abbe noticed a small cloud of the powder, about the size of his hand, emerge from the tube and then fall to the carpet, about a yard below, where it became invisible to the eye. To recover the radium Abbe placed photographic plates over the spots where the cloud landed. The plates' images helped him to precisely locate the particles (figure 5.9). He cut out the piece of the carpet containing the radium and sent it away to recover the radium.

Abbe admitted that when he sealed the radium in the glass capsule a collegue had recommended fusing a thin platinum wire to the glass to draw off static charges but he omitted this step. After the radium had been recovered it was re-sealed in a glass capsule but this time with a platinum wire fused to it.

Radium chloride and bromide salts were difficult to keep completely dry because they were hygroscopic — i.e., they readily absorbed moisture from the air. To eliminate the risk of radiolysis of water, SCC chemists converted the radium bromide salts to sulfates which are not hygroscopic.[234]

Glass capsules were formed from glass capillary tubes that were flame-sealed on one end, filled with the radium salt, and flame-sealed on the other end. Loading the radium salt powder into the capillary tubes was a delicate operation requiring patience, a steady hand, and a fine eye to use a micro-spatula to lift the powder from the silica beaker, pour it into the narrow tubular space inside the capillary tube, and then, using a thin mandrel, packing the powder (figure 5.10). The process was called "tubing." Eventually, metal replaced glass to encapsulate the radium. Metal capsules were more robust and avoided the static problems associated with glass. The powder was placed into the open end of a metal capsule. It was capped with a friction-fitted plug that was sealed with gold solder.[235]

Radium salts and sources were stored in the rear part of the Oakland Savings and Trust Company's vault on the first floor (figure 5.11). A partition separated the bank and SCC sections and the SCC section had its own door for private access.

* * *

Radium Chemical Company (RCC), a subsidiary of SCC, handled marketing and sales of radium. Information brochures (figure 5.12) described RCC's products.[236] Purchasers signed formal sales agreements that specified the amount of radium element being purchased and its cost. In addition to the Pittsburgh sales office RCC established branch offices in Baltimore, Boston, Chicago, New York, Philadelphia, and St. Louis, each headed by a physician.[237] Sealed medical radium sources were delivered to physicians in a leather-covered hinged box. Nestled inside the velvet-lined interior was a polished, engraved, stainless steel hexagonal container for the sources. (figure 5.13). Each source was accompanied by a calibration certificate stating the composition of the radium salt and amount of radium element. The certificate was boldly inscribed with SCC's name and featured a vignette of the Vanadium Building with a pennant flying atop the roof labeled "RADIUM". A brilliant blue, filigreed border framed the technical data about the source. Each certificate was signed by the SCC chief physicist, Leslie Walker, and the radium laboratory director, Charles Viol, and counter-signed by Joseph Flannery. An embossed gold seal completed the certificate. This presentation was sure to leave a favorable impression of the company that produced the radium. These were not the only marketing props. Each physician purchasing radium for medical use received a massive compendium of radium therapy case abstracts, technical information on equipment and techniques, and glossary.[238] Its cover was embossed with the physician's name.

A Philadelphia physician G. J. Schwartz probably became the first American physician to receive American-made radium when SCC loaned 1.7 millgram to him on April 1, 1913.[239] The source, part of SCC's first commercially produced radium, was delivered by Otto Brill. At the time American demand for radium was one-seventh of European demand but sales to Europe had been brisk and contracts were signed for deliveries well into 1914.[240] The onset of World War I in 1914 closed the European market and SCC was forced to suspended production for three and one-half months.[241] As a result the company produced only 9.6 grams in 1914 rather than its planned production of 12 to 15 grams.[242]

If SCC were to survive and prosper, developing a domestic market for medical radium was a necessity. Having honed his marketing skills in promoting vanadium Flannery applied them to promote medical radium in the U.S. SCC inaugurated an extensive medical radium research program in Pittsburgh that included a pathology laboratory, conducting clinical trials, and a free radium clinic. Viol became Research Director and William H. Cameron, MD, an 1899 University of Pittsburgh Medical School graduate, was appointed Medical Research Director (figure 5.14). Cameron had been in charge of the laboratories of the Western Pennsylvania Hospital in Pittsburgh and was Assistant Secretary of the Pennsylvania Medical Society.[243]

Viol assembled a talented team of chemists, physicists, and pharmacists to refine the radium salt, produce and calibrate medical radium sources, manufacture proprietary radium medicines, and provide technical support to physicians and surgeons using radium. A prominent member of his team was Glenn Donald Kammer, a 1912 University of Pittsburgh chemistry graduate who became Assistant Director. Emil Krapf, a Doctor of Pharmacy from New York City, lead the pharmacy staff and Lester V. Walker, a Cornell University graduate, was Chief Physicist.[244] On the medical side, Frederick Proescher, MD, a Swiss pathologist at the Allegheny General Hospital, was named Director of the Laboratory for Experimental Therapy and Dr. Cameron oversaw the radium clinic and the medical research staff.

Research results appeared in a company journal, *Radium*, which was co-edited by Viol and Cameron and first published in April 1913 (figure 5.15). Ten thousand copies were distributed free of charge to the medical community.[245] *Radium* may have been inspired by the

French journal, *le Radium*, first published in 1904 as a house journal for the French radium supply company founded by Armet de Lisle. Another model for the journal, one closer to home, may have been *American Vanadium Facts,* first published in March 1911 as a house journal for the Flannery's American Vanadium Company. Besides reporting in-house medical radium research, *Radium* reprinted medical radium physics, biology, and therapy articles from other sources, and published notices of news and research developments in the field. In later years, other radium manufacturers in the U.S., such as the Radium Company of Colorado, followed suit with their own house journals (e.g., *The Radium Therapist*).[246]

SCC's medical research was rewarded in 1914 when the American Medical Association (AMA) Council on Pharmacy and Chemistry accepted for inclusion in its list of new and non-official remedies radium salts contained in sealed sources, and in solutions for subcutaneous injection, drinking and bathing, and in compresses. The AMA also accepted the use of radon, the radioactive decay product of radium, dissolved in water for ingestion, for inhalation, and in sealed sources. SCC advertised the AMA's action in its journal, *Radium*[247] (figure 5.16). In 1917, another SCC medical product was accepted by the AMA, "Standard Radioactive Earth," consisting mostly of silica mixed with a small quantity of carnotite.[248]

In June 1916, during the annual meeting of the American Medical Association in Detroit, a group of physicians met to consider creating a professional society dedicated to radium therapy.[249] Although there is no record of their identities, it is certain one of the physicians was Cameron. Following this meeting invitations were extended to radium therapists and physicists to attend a dinner and organizational meeting on October 26, 1916 at the Rittenhouse Hotel in Philadelphia where the Clinical Congress of Surgeons of North America was being held. Philadelphia radium therapist Dr. H. K. Pancoast, in charge of the dinner, introduced the acting president, Dr. W. H. B. Atkins, a Canadian radium therapist from Toronto. The attendees unanimously agreed to create an organization to advance the study of radium therapy, adopted a constitution and by-laws, elected officers, and named the organization the American Radium Society (ARS). Dr. Atkins was elected the ARS's first president.

Active membership in the ARS was limited to physicians experienced in radium therapy and non-physicians specializing in the study of radioactivity were eligible for associate membership. A Committee on Membership was tasked with determining qualifications for membership; Cameron was appointed Chairman. The 1916 dinner meeting concluded with an address by SCC Research Director Charles Viol, "Radium Emanations from the Physical Standpoint." The twenty-two persons attending this meeting became recognized as Charter Members of the ARS — twenty-one physician members and one, Viol, an associate member.[250] The role of the SCC in the creation of the ARS cannot be overstated. In 2016, the ARS meeting celebrated its 100th Anniversary by meeting again in Philadelphia where it held a session on the history of the ARS. Session Chair Dr. Martin Coleman reviewed the founding and early years of the society and noted Viol and Cameron had actively lobbied other physicians to form the ARS and, from their perspective, the purpose of the ARS's founding was to help SCC sell radium.[251]

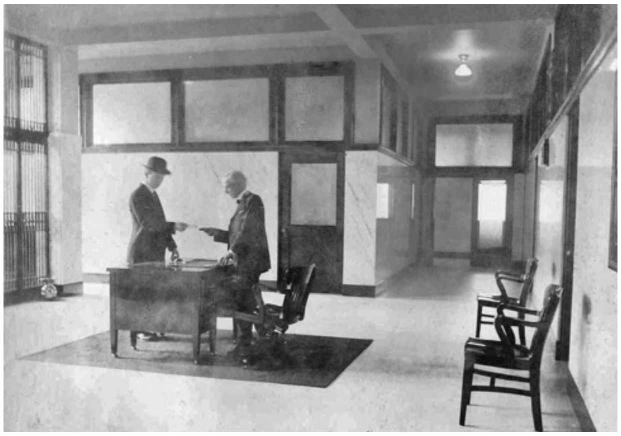
SCC's outreach to the medical community included exhibiting at medical society meetings.[252] For example, in September 1913, SCC displayed more than 100 milligrams of radium in applicators, solutions, drinking and bath waters, compresses and earth at the annual meeting of the Pennsylvania Medical Society in Philadelphia.[253] Later in the year similar displays were exhibited at the Tri-State Medical Association in Memphis, Tennessee, and the Southern Medical Association in Lexington, Kentucky.[254] In September 1913, SCC took part in the 3rd International Pharmaceutical Exposition held in Vienna Austria and received a gold medal for its display of radium products.[255] The company also provided speakers and showed short documentary films of its operations, the last being a novel source of publicity. The films were produced by Pathé, now British Pathé, a company that began making newsreels in 1910. They also made *cinemagazines*, short movies that highlighted selected subjects, producing different versions tailored for specific audiences, e.g., English, American, school, medical, technical, etc.[256] Marie Curie was made aware of the Pathé radium *cinemagazines* during her 1921 visit to SCC, later writing that "The factory owns a collection of documentary film which enable one to appreciate the effort made each day in collecting the ore scattered in the immense fields of Colorado, in carrying and concentrating this ore originally very poor in radium."[257]

Thanks to SCC's remarkable technical accomplishments to produce radium, its medical radium research program, and its promotional efforts, the domestic medical radium market grew. As a measure of its impact consider that in 1909, when Joseph Flannery sought radium to treat his sister's cancer, only three American physicians were seriously engaged in radium therapy: Robert Abbe in New York, Howard Kelly in Baltimore, and William J. Francis H. Williams in Boston. When commercial production of radium by the SCC began in 1913 most of its early production was exported to Europe. In 1916, when the ARS was organized — abetted by the SCC — twenty-one physicians were charter members. Just two years later, 1918, its membership had more than doubled to fifty-three physicians.[258]

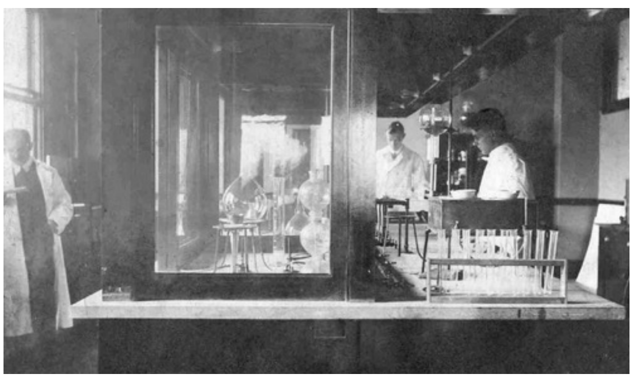
SCC's merging of large-scale commercially sponsored medical research with product marketing was unprecedented; Maria Rentetzi described it as a "radical innovation."[259]

* * *

Joseph Flannery succeeded in producing radium in America. SCC, the company he launched, became America's first nuclear industry. A solid groundwork had been laid for creating and promoting a domestic market for radium. But, as the end of 1913 approached, Flannery discovered he had to deal with a threat from an unexpected quarter — the federal government.



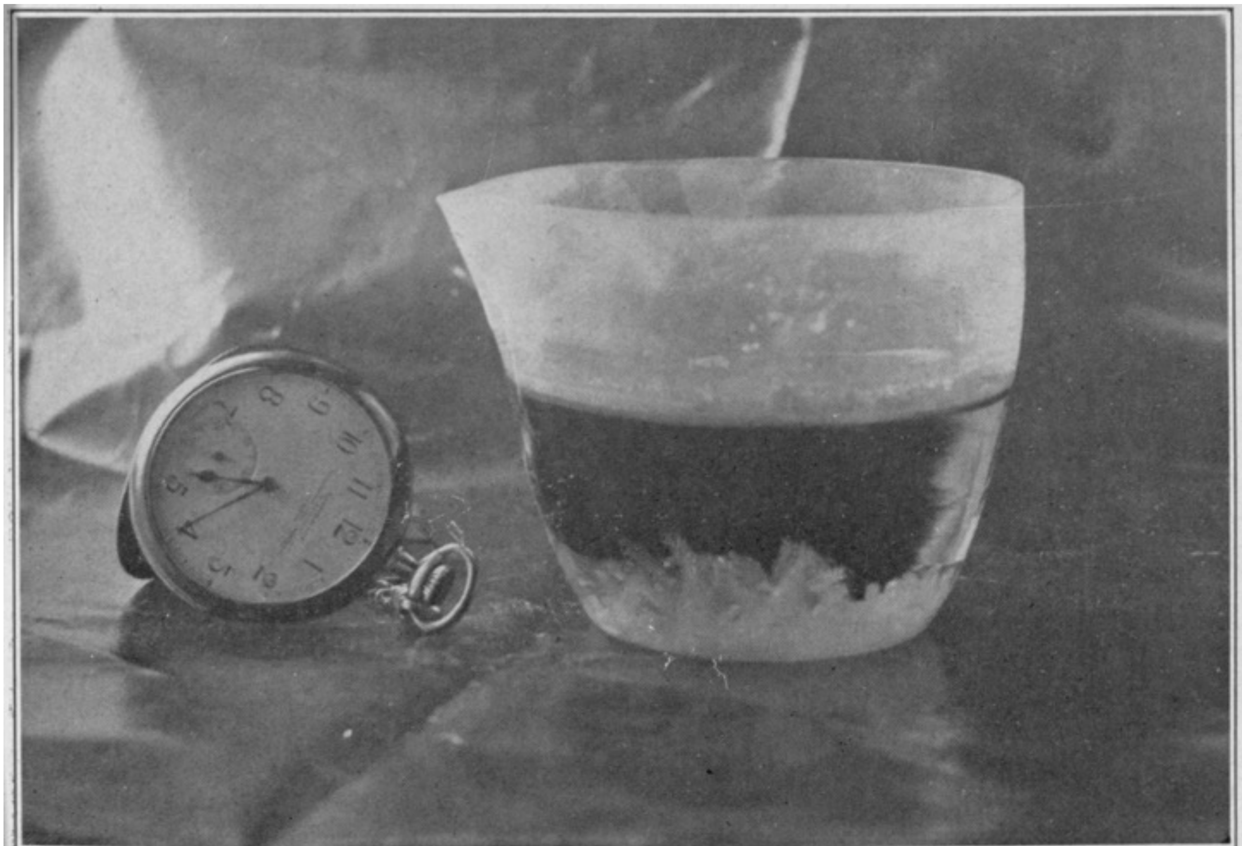
5.1 Left, the reception area for SCC corporate offices on the second floor of the Vanadium Building. *ORAU* 5.2 Right, Joseph M. Flannery's office, remarkably unpretentious. *ORAU*



5.3, 5.4, 5.5 Scenes of the radium laboratories on the 4th and 5th floors. In the top right photo, the gentleman on the left is Glenn D. Kammer. *ORAU*

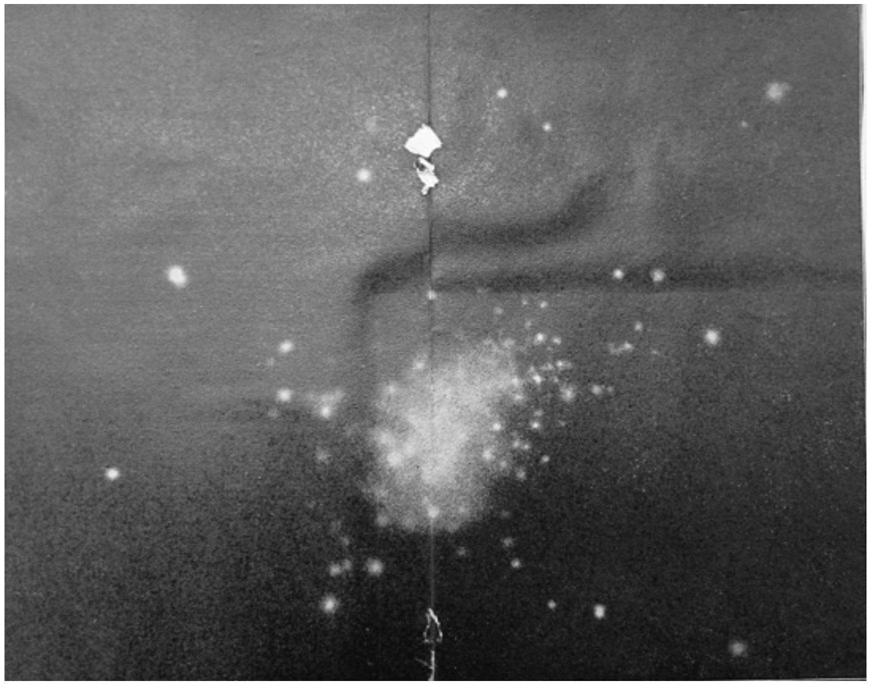
5.6 The fractional crystallization laboratory was in the northeast corner of the 5th floor. Over each burner is an asbestos sheet with a circular cutout to hold the round-bottomed porcelain bowls containing the radium-barium salt solutions. Overhead is a hood to vent the steam and acid fumes. The progression of the process is reflected in bowl sizes – the salts in the smaller bowls contain richer concentrations of radium. Photo c.1915. On the right is Glenn D. Kammer. *ORAU*

5.7 A later view of the fractional crystallization laboratory, c.1921. *HHC3*

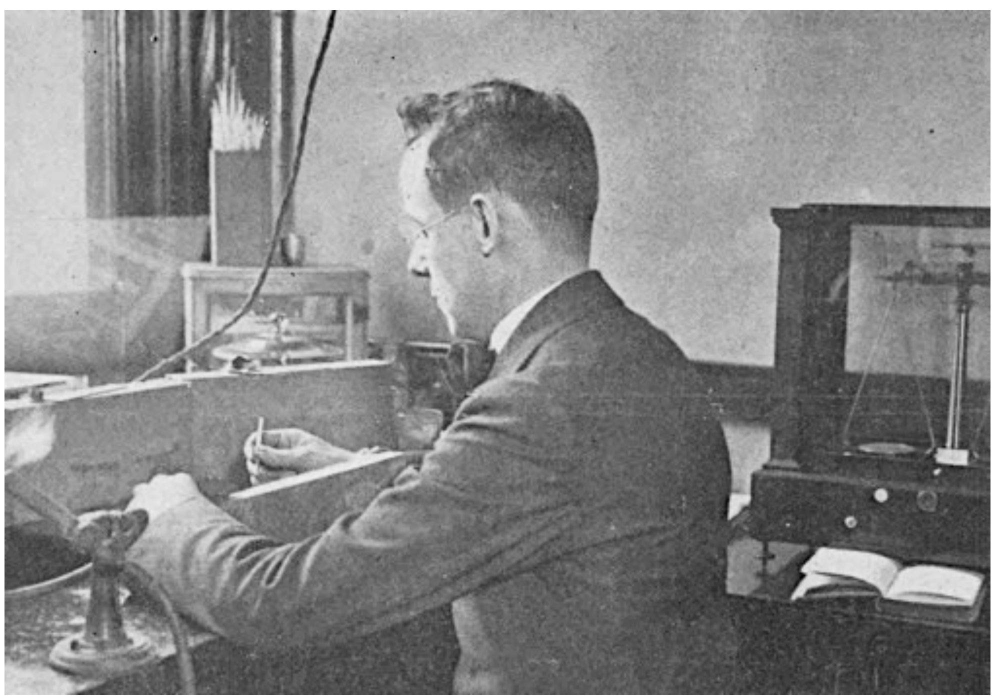


Final stage in the crystallization of Mme. Curie's gram of radium in the Radium Research Laboratory of the Standard Chemical Company at Pittsburgh, Pa. The silica dish shown contains over two grams of radium, in form of radium barium bromide. This represents all the radium from a thousand tons of milling carnotite ore.

5.8 The final product of the fractional crystallization process. The beaker is pure fused silica. The beaker was then heated to evaporate the solvent. The image is from the June 1921 issue of *Radium*. *CCP*

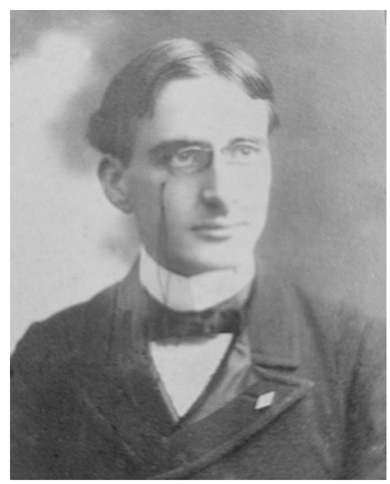


5.9 Dr. Robert Abbe's autoradiograph of the carpet where he saw a cloud of radium powder fall following an explosion of a a glass radium capsule. The autoradiograph confirmed Abbe's visual observation. That part of the carpet was then cut out and the radium subsequently recovered. *CPP*

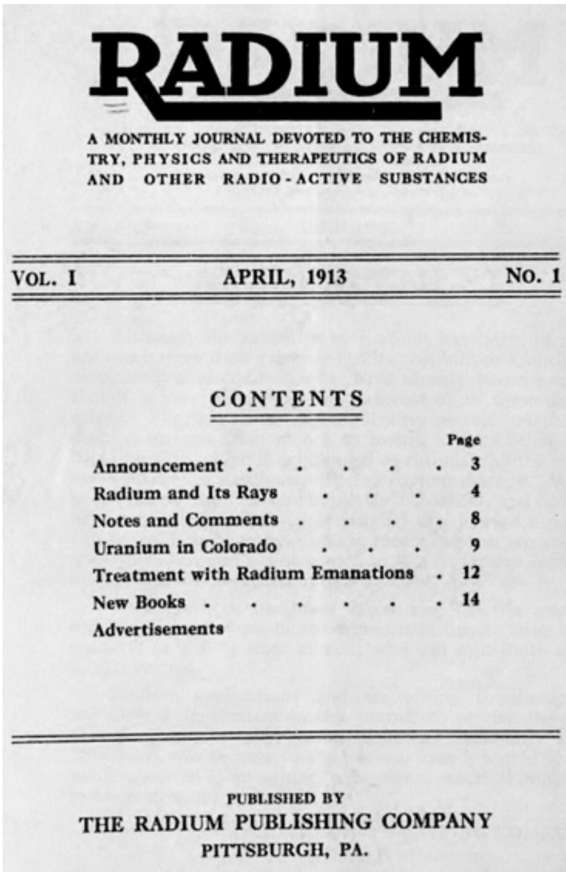


5.10 Left, Glenn D. Kammer tubing Marie Curie's radium, c. 1921. There are no contamination controls. A lead "shadow" shield in the front is a recent addition to reduce radiation exposure of his torso. *CPP*

5.11 Left, SCC stored its radium in a walk-in vault on the first floor of the building. The vault was shared with the Oakland Savings & Trust Company, a Flannery enterprise. The rear section of the vault, used by SCC, was separated from the bank's section by a divider and had its own door. *ORAU* 5.12 Right, RCC information brochures about radium therapy. *CPP*



5.13 Left, RCC sealed radium source products and packaging. On the left in the foreground are examples of glass tubes containing radium that were then inserted inside the metal tubes behind them. These were inserted into an engraved steel container, shown on the center and right, that was placed in an embossed leather covered, felt-lined case, on the right. On the left is the shipping box complete with wrapping paper, cords, and a wax seal — an impressive package. *ORAU* 5.14 Right, William H. Cameron, MD, SCC Medical Director. Photo taken in 1899 upon his graduation from the University of Pittsburgh School of Medicine. *UP2*



RADIUM

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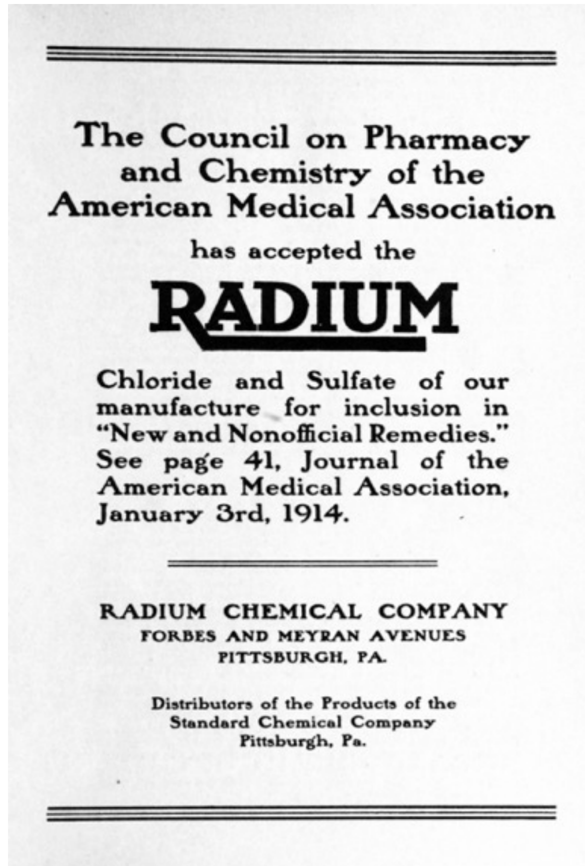


5.15 Left, the cover of the first issue of *Radium*. *JOL* 5.16 Right, an example of the advertising by SCC of its medical radium products, in this case, touting the decision of the American Medical Association to include RCC's medical radium products in its "New and Nonofficial Remedies." *JOL*

Chapter 6: Joseph M. Flannery Versus the U. S. Government
"We were not in the liquor business at the time"

On October 23, 1913, Charles L. Parsons, Chief of the Division of Mineral Technology of the U.S. Bureau of Mines (USBM), part of the Department of the Interior, addressed the American Mining Congress at their annual convention in Philadelphia.

Entitled "Our Radium Resources," he began his talk by noting that almost all of the carnotite mined in 1912 had been shipped abroad and that the Colorado carnotite was furnishing three times as much radium as the rest of the world. He asserted there was a large waste in mining carnotite because low-grade ores that were relegated to dumps would have economic value if they were mechanically concentrated. Parsons pointed out there was a large gap between the money paid in Europe for the ore and the money paid to American miners. To close the gap he offered two options, holding U.S. ore for a higher price or manufacturing radium in America.

Parsons' speech proclaiming that the radium resources of the nation needed to be conserved for the benefit of the American people was the public face of moves within the Department of the Interior and within the Progressive wing of the U.S. Congress pushing for government control of mineral resources. Carnotite ore was such a resource that, thanks to the USBM, entered the public spotlight. When Woodrow Wilson became President in March 1913, he appointed Franklin K. Lane, (figure 6.1) Secretary of the Interior. Lane proposed the government conduct exploration and research to develop a supply of radium and withdraw public lands containing carnotite and other radium-bearing ores. He explained the term "withdrawal" meant not from use but from exploitation by private parties and developing the ores for the "service of the people of the United States."[260] If passed by Congress, the practical effect of the proposal would be an end to filing radium mining claims on federal lands. Existing claims would be honored, but new claims would be subject to control by the Secretary of the Interior with the objective of securing a supply of radium "for the use of the Government of the United States and the hospitals of the country."[261]

Parsons closed his talk with an announcement that the USBM had entered a cooperative agreement with the newly organized National Radium Institute (NRI) to conduct a study of the mining and concentrating of carnotite ore with the objective of increasing efficiency and minimizing waste.

The NRI was organized by physicians Howard A. Kelly of Baltimore and James Douglas, Jr. of New York (figures 6.2 & 6.3). Kelly, renowned for his pioneering work in treating gynecological cancers became acquainted with radium therapy in 1907 and moved quickly to acquire radium for his private hospital, the H. A. Kelly Hospital in Baltimore.[262] From 1907 to 1913, he purchased 1,180 milligrams from suppliers in Vienna and Paris and from SCC. He desired more, but supplies were limited.

James Douglas. Jr. was president of the Phelps Dodge Corporation. Born in Canada, he trained as a physician but turned to chemistry and copper metallurgy.[263] He moved to the United States joining a predecessor company of Phelps Dodge as a consultant. On his advice, the company acquired copper mines that became a major source of the metal and in 1909 he became company president. Like Flannery, cancer struck a member of his family — a daughter who was stricken with breast cancer. Despite surgeries and treatment with radium his daughter died in 1910, the same year as Flannery's sister. Douglas turned his attention to philanthropic work to provide radium for hospitals. Douglas' and Kelly's interests joined when Kelly, noting the existence of radium institutes in Europe, campaigned for an American radium institute to supply radium for American physicians.

In Europe national radium institutes had been established with governmental and philanthropic support to promote production and study of radium but there were none in America.[264] In 1912, Samuel C. Lind, a University of Michigan faculty member who spent a year at radium laboratories in Paris and Vienna, attempted to establish an American institute but was unable to obtain financial support; later Kelly mounted an effort but was also unsuccessful.[265] Douglas followed different approaches, first by donating $100,000 to General Memorial Hospital in New York City to foster cancer research and treatment at the hospital and secondly by directing a metallurgical engineer employed by Phelps Dodge, G.D. Van Arsdale, to develop lower cost methods to produce radium. After consultation with U.S. Geological Survey (USGS) scientists, Van Arsdale set up a pilot plant to treat ore but the plant was abandoned after experiencing high losses of radium in the process.[266]

In 1912, the USBM decided to set up a project in Denver Colorado to investigate and improve the mining, concentrating and processing of radium ores but lacked a federal appropriation for it. USBM sought private parties to fund it, and Kelly and Douglas expressed interest. USBM proposed the two men establish NRI to produce radium for hospitals and furnish the capital and USBM would furnish technical staff. Kelly and Douglas agreed and each provided $75,000.[267]

* * *

On January 19, 1914, the House of Representatives' Committee on Mines and Mining, chaired by Illinois physician Dr. Martin D. Foster (figure 6.4) opened a hearing on House Resolutions 185 and 186, bills intended to implement Interior Secretary Lane's proposal to "withdraw" public lands containing carnotite and other radium-bearing ores.

The House hearing attracted considerable press attention because at that very time, Kelly was treating 39-year old Representative Robert G. Bremner of New Jersey (figure 6.5) in Baltimore with radium for a cancer in the shoulder–neck region. Bremner had a huge tumor that encircled his shoulder blade, upper chest and underarm area. Previous treatments to slow the growth or reduce the size of this mass had been unsuccessful. In mid-December 1913, Bremner encountered Parsons at a restaurant. Bremner had been fitted with a harness that raised his left arm to head-level.[268] On learning of his condition, Parsons suggested that he see Kelly for radium treatment and on Christmas Day of 1913 Kelly operated on the Congressman at his private hospital.[269] The surgical treatment involved the use of almost all of Kelly's radium, about a gram, in 11 tubes that were surgically inserted into the tumor for a period of 12 hours. The treatment was repeated two days later, but this time the radium tube array was applied externally.[270] Initial results were encouraging, for example, on January 12, 1914, Bremner for the first time in months, was able to move his head, and as late as January 29th he was reported as improving.[271]

The massive amount of radium that Kelly employed and his public statements about Bremer's condition raised eyebrows among other physicians. While still treating Bremner in January 1914 Kelly came under scrutiny by the Committee on Honor of the Medical and Chirurgical Faculty of Maryland (today known as The Maryland State Medical Society) for medical ethics violations in connection with his frequent public statements on radium and its effects.[272] Kelly declined to respond to newspaper inquiries and complained his views on radium and its effects had been misrepresented.[273] When the House committee hearing on Lane's proposal opened, Kelly was asked about Bremner and he replied that he did not consider his case hopeless but wished he had more radium.[274]

While it received far less attention than the Bremner case, SCC General Counsel James Gray's testimony about his experience with cancer was a graphic reminder of the primitive state of cancer treatment in this era and the hope that radium offered to its victims.[275] Gray had a fast-growing malignant bone tumor on the spine. Between the spring and fall of 1913, he had four surgeries in Philadelphia and in Pittsburgh and was severely burned by an x-ray treatment used as an adjunct to the third surgery. Around September 1913, he began radium treatment of the wound region. The tumor was at this point about the size of two hands, and its growth was tearing the wound open and required constant dressing. It is likely that SCC's Medical Director, Dr. William Cameron, was involved in the radium treatment and that the radium was some of SCC's earliest production.

The radium treatments halted the growth of the mass and enabled a surgeon to later remove the tumor with minimal dissection. At the hearing, Gray, who still had an open wound and had just received another radium treatment days before described the lead-up to his last surgery:

> I had the radium applied during the time I waited until the operation was performed…I had it applied only twice by the doctor. On every other occasion it was applied by Mrs. Gray. I would get the radium as I would go home at night, and she would put the radium on my back and strap it in place, and take it off in the morning. The radium would be taken back, and the same radium that I used that night was used in three different hospitals during the day.[276]

Thanks to Cameron's radium therapy Gray became a cancer survivor. He died eleven years later, May 1, 1915.

* * *

SCC's top priority was defeat of the Lane proposal. Withdrawal of public lands containing carnotite would seriously damage SCC's long-term prospects because the company's existing claims would last no longer than eight years.[277] Another concern was rebutting suggestions of monopolist control of carnotite ore that Kelly had raised.[278] To counter this SCC, represented by Joseph Flannery, Charles Viol, Dr. William Cameron, and James Gray sought to portray the SCC as a technical innovator and free market pioneer operating in uncharted waters. They touted the company's efforts to educate American physicians on the benefits of radium and thereby develop a domestic market for American radium. The extent of their testimony is reflected in the printed record of the House hearing; of its 271 pages, SCC's testimony filled 141 pages, over half. Nonetheless, SCC's assertions were challenged and the most withering questions were directed at Flannery. They came from Representative James F. Byrnes of South Carolina (figure 6.6).[279] and it was another Flannery company product, vanadium, not radium, that provided Byrnes' best ammunition.

At the time there was no government program for approving pharmaceuticals. To assist practicing physicians in sorting through the medical-products marketplace, the American Medical Association (AMA) established a program for reviewing and listing "New and Nonofficial Remedies." In 1908, the AMA published a response to an inquiry about medical use of vanadium stating that "The claims made for vanadium have not led to its wide use and until they are confirmed by reliable clinicians the remedy must be regarded as in the experimental stage."[280] In 1909, the AMA responded to another inquiry.[281] The name of a proprietary vanadium medicine, "Vanadioserum Helouis" (see chapter 1) was called misleading and, regarding vanadium itself, the AMA stated "The use of this rare element does not appear to be a promising field for experimentation," and suggested that physicians wishing to try it should obtain it through a chemical supply house rather than proprietary preparations.

In 1912, the AMA published a lengthy critique of fraudulent fat-reducing claims made by Francis M. Turner, the general manager of the Vanadium Chemical Company (VCC), a subsidiary of the AVC.[282] Turner had claimed to be a physician, but the AMA found that he did not have a state license. Moreover, he was using his position at VCC to promote a fat-reducing business ("Turner Obesity Cure") in collaboration with other companies, none connected with VCC. Turner was also linked to other fraudulent health products of which all deemed quackery by the AMA. With respect to VCC's proprietary vanadium medicines AMA described them as "so-called ethical proprietaries," but did not otherwise did not address their merits. But given the AMA denunciation of Turner, VCC's claims for its proprietary vanadium medicines became suspect. With Turner exposed as a fraud who used his position at the VCC to promote an obesity cure that had no connection with the VCC, the prudent step for VCC would have been to promptly terminate its association with Turner, but that this was not done until his contract expired.[283]

The final blow was delivered by the AMA in the midst of the Congressional hearings on radium. The VCC had asked the AMA list its vanadium-bearing medicines in its "New and Nonofficial Remedies." The AMA refused the request, citing the company's failure to provide clinical evidence of the products' efficacy.[284] Again denouncing Turner for fraudulently using the title, "M.D.," and his connection to the fraudulent obesity cure, the AMA noted that the VCC "still retains him as a general manager!" (emphasis in the original). The AMA concluded that the VCC medical preparations should be refused recognition but did not go so far as to characterize them as quack products. Still, the damage was great because of the AMA's linkage of the medicines to Turner: "While there is not necessarily any direct relation between the personnel of a proprietary manufacturing company and the value of that company's product, it is natural that the medical profession should view with distrust any concern managed by one who has previously been connected with such a fraud as the Turner obesity cure." In their testimony Flannery and Cameron, pointed out there was no connection whatsoever between the VCC 's production of vanadium medicines and SCC's production of radium for medical use, but Byrnes exploited Flannery's past association with the VCC to disparage the SCC. During Byrnes' questioning of Flannery about the VCC's promotion of vanadium medical products, he taunted Flannery about a wine containing vanadium that Helouis had sold at The Vanadium Hotel, asking why it was not added to the VCC's product line. Flannery met taunt with retort: "Well, we were not in the liquor business at the time."[285]

On January 26th, Lane informed the committee of the progress of the USBM-NRI agreement -— NRI had completed purchase agreements for ore, was constructing a radium extraction plant in Denver that it planned to place under the technical supervision of USBM staff and pay for the operation of the plant.[286] NRI would take possession of the first 7 grams of radium produced by the plant with the balance going to the USBM. Kelly and Douglas offered to turn the plant over to the USBM without charge upon termination of the agreement. Regarding the radium intended for USBM, Lane stated that the Attorney General had ruled that the USBM could not make any contractual claim on the radium produced by NRI in return for its technical support but it could be accepted as a gift from the NRI.

The House hearing concluded on January 28th. It was clear by then that withdrawal of radium-bearing public lands was strongly opposed by western mining interests and by House representatives from Colorado and Utah who insisted that the government not "lock up" such lands. Ironically, the hearing itself had had an unexpected effect: talk of federal withdrawal of radium lands resulted in a rush to file carnotite mining claims.[287] A Utah a printer in southeastern Utah said that his shop had sold almost a thousand claim forms during the January rush, and *The New York Times* reported that at the end of the rush "there would be little land left to withdraw."[288]

Following the hearing, committee members met to draft a compromise radium bill.[289] They recommended a modified Lane plan (H.R. 12741) that, instead of withdrawing public lands, gave the government a preferential right to purchase radium-bearing ore mined from government-owned lands at prices fixed by the Secretary of Interior.[290] The bill also authorized $150,000 to pay for the construction of the radium extraction plant in Denver and $300,000 for purchase and treatment of radium-bearing ores.

Meanwhile, Bremner's medical condition took a turn for the worse. Following a setback on February 1st it became clear his battle would soon end and on February 5th Bremner died.[291] President Wilson sent his condolences to his widow and the House passed resolutions expressing regret for his death.[292]

The Senate hearing began February 10th, five days after Bremner's death. Sen. Thomas J. Walsh, Montana (figure 6.7) chaired the committee and introduced the modified Lane plan as

Senate Bill 4405. Bremner's death loomed large in the Senate hearing. In his Senate testimony, Flannery, in response to a question from Senator Miles Poindexter of Washington, bluntly stated "They probably killed Representative Bremner with radium."[293] Flannery, probably under advice from the SCC staff and counsel, subsequently asked to correct his response for the record, stating "Probably too much radium was applied in the hope of saving Mr. Bremner's life, which possibly threw back into the system too much poison for the then depleted system to take care of."[294] Even so, the following month, Dr. James Ewing, Professor of Pathology at the Cornell University Medical School, essentially confirmed Flannery's original statement when, at a special meeting of the American Society for the Control of Cancer, he commented that the radium dosage to Bremner was excessive and hastened his death.[295]

The last day of the Senate hearing, February 24, 1914, opened with testimony from Dr. John F. Anderson, Director of the Hygienic Laboratory of the U.S. Public Health Service (USPHS).[296] Anderson showed the senators graphic photos of five patients who had undergone radium therapy. The first four sets of photos were before- and after- images of a malignant tumor of the hand, of the lip, of lymph glands of the neck, and the forehead (sarcoma of frontal bone). All showed the radium treatment resulted in remarkable reductions in tumor size in the patients. The fifth image (figure 6.8) told a very different, far less hopeful tale. The front and back photographs (face fully obscured) showed a man's bare torso with a huge growth enveloping the entire left shoulder and were captioned "Two views of a much discussed case, which was not cured, but which with sufficient radium would probably been easily cured at an earlier stage." The patient, not identified, was probably Bremner. Anderson pressed hard for including the photos in the hearing record. Chairman Walsh initially thought there was a rule against that but they were reproduced in the final document from the Government Printing Office.[297]

USBM Director Dr. Joseph A. Holmes provided testimony about the financial advantages of government production of radium for government hospitals. Holmes stated the amount of radium available to American hospitals was only about 2 grams. In contrast, the U.S Army and Navy wanted 10 grams of radium for their hospitals and the U.S. Public Health Services wanted 20 grams for its hospitals. At $120,000 per gram Holmes pointed out 30 grams for the Army, Navy and Public Health Service hospitals would cost the government $3,600,000 ($91,300,000 in 2018 dollars) adding that he believed the USBM could produce the radium at less than one-third of that figure.[298] Holmes attributed much of the difference to the profit made by private producers.[299]

* * *

Congress did not act on any of the bills.[300] No federal funds were authorized for the NRI extraction plant. Its construction and subsequent operation went forward using the $150,000 contributed by Kelly and Douglas with technical support provided by the USBM staff. By June 1914 the plant was in operation. NRI was fortunate in gaining access to exceptionally high-grade ore, averaging about 2.5% U_3O_8, from mines in a favorable location that minimized freighting costs. Plant recovery of radium averaged 90%. NRI's progress was sufficiently encouraging that Kelly and Douglas increased their investment in the NRI to $500,000 to finance construction of a second extraction plant and other improvements.[301] In light of this, they negotiated an amendment to the USBM – NRI agreement that increased their share of the radium produced by the NRI and reduced USBM's share to 0.5 gram.

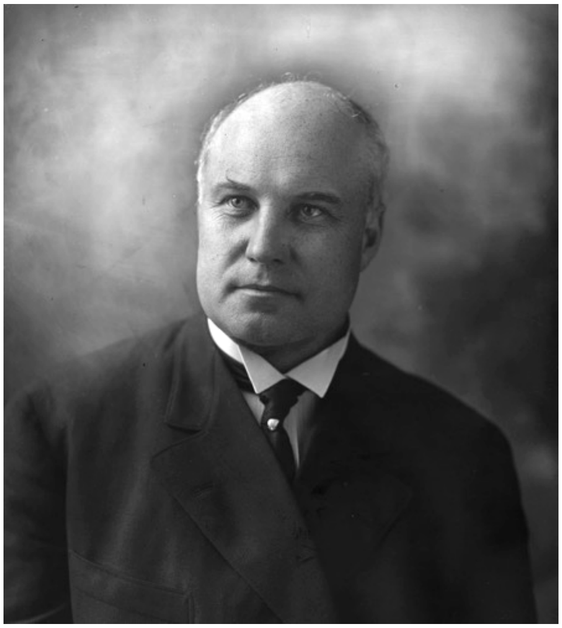
The NRI operation ended in 1916. It produced 8.5 grams and the USBM claimed the average production cost was $37,599 per gram.[302] This, of course, led to charges of SCC making excess profits.[303] The SCC counterattacked pointing out that NRI selectively used higher-grade ores than normally available and had lower shipping costs. It also did not carry the costs of medical research and marketing programs to develop a domestic market for radium, did not pay for the USBM staff providing technical support, and ignored the profit element required in the private sector.[304] NRI's cost figure was the proverbial "lowball."

After consigning 0.5 gram of radium to the USBM, Kelly and Douglas split the remaining 8 grams. The acquisition of this amount for their investment of $500,000 meant it cost them $62,500 per gram, nearly half as much as the prevailing price of $120,000 per gram. The cost of the USBM's technical supervision was paid out of a U.S. Government annual appropriation of $100,000 for experiments in treatment of ores, part of the USBM operating budget.[305] In other words, U.S. taxpayers subsidized the production of the radium that Kelly and Douglas received.

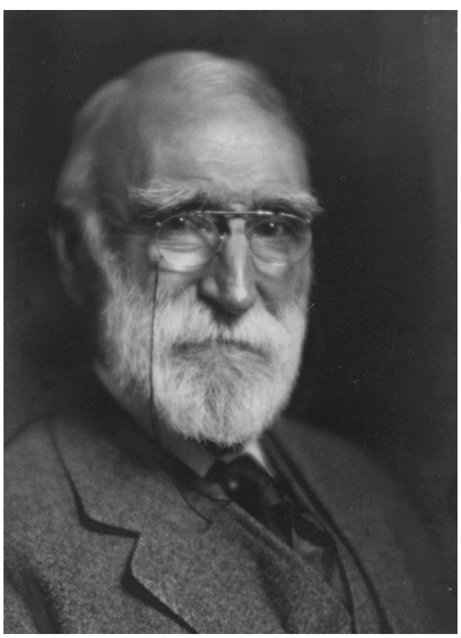
Douglas donated his radium to the General Memorial Hospital (now Memorial Sloan Kettering Cancer Center) in New York City but Kelly's radium went to his private hospital in Baltimore.[306] He now owned 5.5 grams of radium, the largest private supply in the world, most of which had come from the NRI.

None of the Army, Navy and Public Health Service hospitals received radium from the NRI.

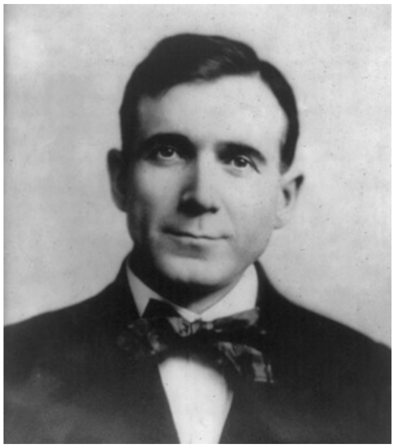
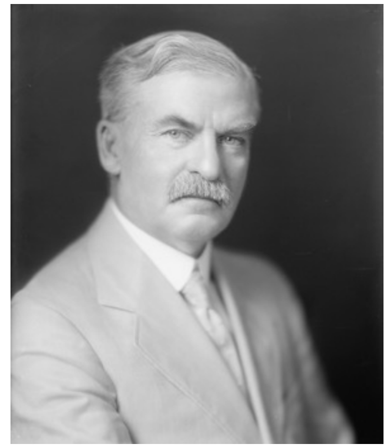
Lane's proposal also called for the Secretary of the Interior to conduct exploration and research to develop a supply of radium. In his House testimony, Flannery "heartily" agreed with this part.[307] After all, SCC had worked with the NBS on establishing national radium calibration standards and here was a new opportunity for collaboration with the government. Flannery's objections were to the other provisions of Lane's proposal, namely those limiting access to radium bearing ores on federal lands and government funding of a federally sponsored entity that competed with SCC. Unfortunately for Flannery, Congress's emphasis was on those parts. In the end, because no legislation was passed, the legal status of public lands containing radium-bearing ores remained unchanged, precisely the outcome desired by the SCC. But Flannery's call for a cooperative approach with the government to develop radium resources went unheeded.



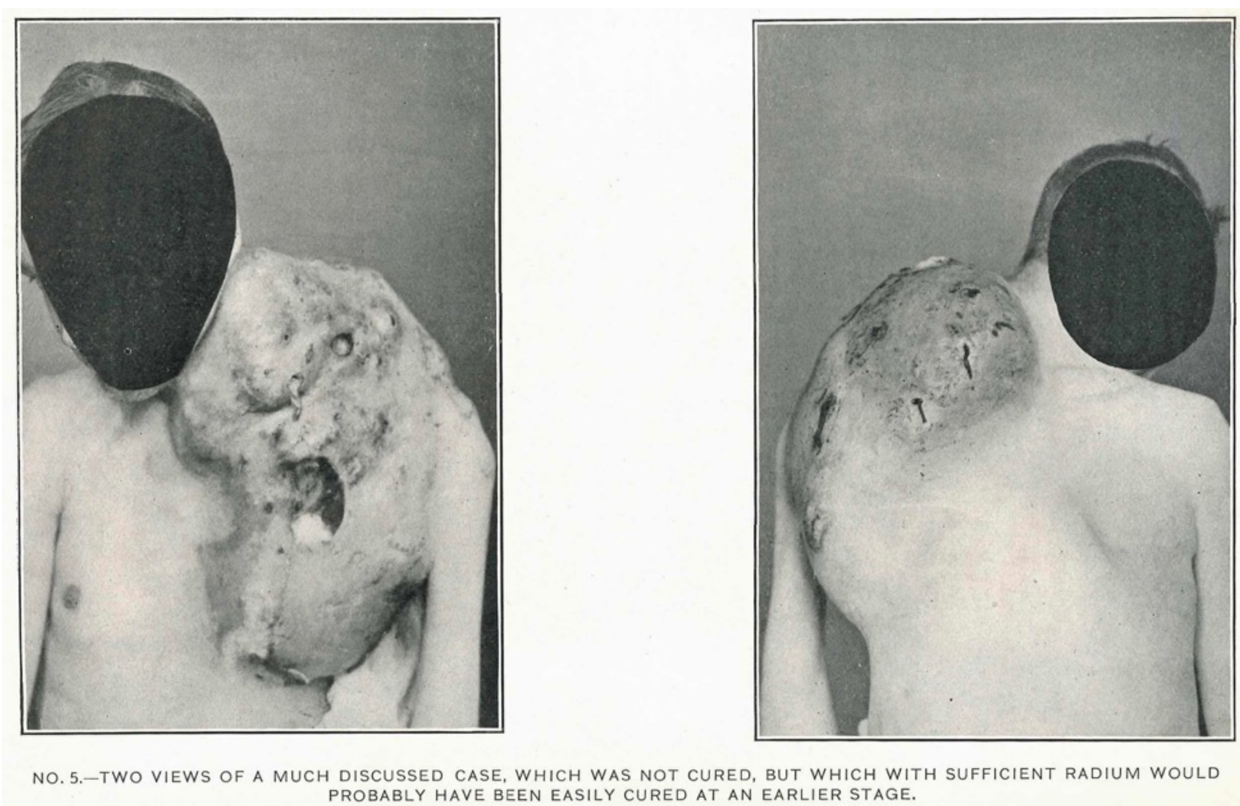

6.1 Left, Franklin K. Lane, Secretary of the Interior. *LOC* 6.2 On the right, Howard A. Kelly, MD; the photo probably taken when arriving at the Capitol during the 1914 Congressional hearings on radium. *LOC*




6.3 Left, James Douglas, Jr., MD. *QU* 6.4 Right, Illinois Representative Martin M. Foster, MD. *LOC*

6.5 Left, Representative Robert G. Bremner of New Jersey. *LOC* 6.6 Center, Representative James F. Byrnes of South Carolina. *LOC* 6.7 Right, Senator Thomas J. Walsh of Montana. *LOC*



6.8 The patient with this massive tumor shown in the published 1914 Senate hearings volume on the nation's radium resources was likely Rep. Bremner. (*USCS)*

Chapter 7: Byproducts

"Streets paved with radium."

The 1914 Congressional hearings on radium also delved into SCC's production and disposition of vanadium and uranium. The metals, components of carnotite ore, had become byproducts of radium extraction and Flannery explained their potential value. Another byproduct was massive quantities of processed ore residue, called "tailings." SCC had found a novel use for the tailings — as an additive to fertilizer, and Flannery, never one to let pass a marketing opportunity, used the hearings as a platform to publicize this product.

*   *   *

There was a ready market for vanadium as an alloying metal to harden and strengthen steel. To a great extent, the Flannery brothers created this market with their American Vanadium Company (AVC). Revenue from the sale of vanadium byproduct contributed to SCC's bottom line. Yet in his House testimony Flannery stated, "We have not found a market for our vanadium," a claim later repeated by Viol, "Well, at present I think I can say with Mr. Flannery that the value is nothing. We have not gotten a cent from that. Our ore is rather low-grade uranium and vanadium ore. It is an expensive proposition to recover vanadium from low-grade ore."[308] Relative to the patronite mined by AVC in Peru, the carnotite was lower grade — the vanadium content of the Peruvian ore ran about 17 to 28 % V_2O_5, versus about 4 to 14% V_2O_5 for the ore from Paradox Valley.[309] So, it was possible that SCC's cost to recover vanadium from the carnotite was not competitive with AVC's cost to recover vanadium from patronite. But it is also possible that, given the charges that the SCC was making excessive profits from its radium production, Flannery and Viol chose to downplay the value of vanadium as a contributor to SCC's bottom line. Indeed, four years later during WWI at a May 2, 1918 hearing of the Senate Committee on Mines and Mining on Minerals and Metals for War Purposes, Flannery testified that SCC was "selling 100 per cent of our vanadium."[310]

In contrast, the market for uranium was limited. Flannery expressed his frustration in finding markets for uranium in his House testimony, "We have on our hands now probably 100,000 pounds…It is stacked up as high as the ceiling. We cannot do a thing with it."[311]

Uranium compounds were used as a coloring agent in the manufacture of glass and ceramics. The coloring varied over a wide spectrum, e.g., greenish-yellow in "Vaseline" and "Canary" glass, vivid orange-red in ceramic glazes, and even black, the colors depending on the chemical characteristics of the uranium compounds and conditions in the firing kilns. Other minor uses of uranium included use of its salts in homeopathic medicine, in chemistry as an indicator, in photography to tint prints, and in the textile industry for calico printing.[312] In the late nineteenth century, European armament manufacturers looked at uranium as an alloying metal to increase tensile strength and hardness of steel and by 1902 their interest sparked a surge in prospecting and mining of vanadium ores in southwestern Colorado.[313] But subsequent metallurgical research in Europe disclosed that other alloying metals such as tungsten could impart similar effects at a lower cost and interest in uranium as an alloying metal diminished.

World War I brought a renewed interest in uranium-steel alloys fueled by rumors that Germany was using uranium steel to increase the rapid-fire capability and accuracy of large gun barrels. In conjunction with the Army and Navy, the USBM sponsored research programs to assess the value of making uranium steel armaments. One problem that came to light was the difficulty of making uranium-steel alloy on a large-scale. Even after that problem was overcome, testing of the alloy failed to show it had any merit beyond existing alloys. Once again, interest in uranium-steel alloys waned.[314]

To create a civilian market for uranium steel, Flannery assigned a second mission to the SCC plant in Canonsburg, production of uranium steel and other metal alloys, and established a subsidiary, Standard Alloys Company (SAC), to market the products. [315] In 1917, Louis F. Vogt, the manager of the Canonsburg radium extraction plant and Robert M. Keeney, plant metallurgist, received patents for a ferro-uranium alloys and a nickel-uranium alloy[316] (figures 7.1 & 7.2). Also, in 1917, Joseph Flannery received patents, three for high-speed steel (steel toughened and hardened to cut metal, e.g., lathe cutting tools) that contained uranium and another patent for a uranium iron alloy.[317] Flannery also sought outside help. In October 1918, he signed a one-year contract with the Mellon Institute to support an industrial research fellowship targeting uranium alloy production.[318]

By1916 Flannery was selling ferro-uranium alloys to specialty-steel alloy manufacturers and in 1921 SAC published a 32-page booklet, "Uranium in Steel" that provided a history and description of uranium, technical performance data for such alloys, and information on the making of the alloys. [319] Flannery had succeeded in establishing a niche market for high-speed cutting tools made of uranium steel.

SCC's most inventive ploy for marketing byproducts was mixing ore residues from the Canonsburg plant with commercial fertilizer and selling it as radium fertilizer. Robert Abbe was one of the earliest Americans to investigate the effects radium on seed growth.[320] In 1909, C. Stuart Gager, a botanist at the University of Missouri, reported his discoveries of the effects of radiation from radium on seed germination, photosynthesis, and alcoholic fermentation.[321] He concluded the radiation could act as a stimulus to such biological activity but becomes an inhibitor if the exposure is too prolonged. In 1913, Colorado State Commissioner of Mines Thomas R. Henahen touted the state's uranium ore for making fertilizer.[322] In February 1914, during the U.S. Senate Hearings on radium Flannery extolled the value of radium fertilizer:

> Radioactive sand, as it comes from our concentrating plant, when given to the farmer and mixed with his fertilizer and used in the ground, is very effective and valuable as a catalyzer. It tones the seed. If the seed is a little anemic or mediocre it brings it up to the normal of the fertilizer. I have had the pleasure of working in some of this material, and in tobacco we have got a 75 per cent increase; in wheat 65 per cent; in corn, 250 per cent; 50 per cent in cabbage. The smallest amount of this material being mixed with the fertilizer affects the seed. You get a thousand pounds of this material and it can be sold at a price to the farmer which will be ridiculously low.[323]

The potential value of such fertilizer was the subject of two field studies. In the spring of 1913, the University of Illinois Agricultural Experiment Station began field experiments with radium fertilizer supplied by SCC.[324] The study was led by University of Illinois Professor Cyril G. Hopkins, Chief in Agronomy and Chemistry, and Ward H. Sachs, Associate in Chemistry. The second study was begun in the fall of 1913 by Henry H. Rusby, Dean of the College of Pharmacy of Columbia University, (figure 7.3) with SCC again supplying the radium fertilizer.[325] While Hopkins and Sachs were the first to conduct experiments Rusby was the first to publish results. They reached very different conclusions.

Rusby's interest in plants harkened to his youth in Nutley, New Jersey. At age 21, his personal herbarium won a prize at the Centennial Exposition in Philadelphia in 1876. He received a medical degree in 1884, and spent 1885-1887 in the jungles of South America collecting medicinal plant materials including cinchona tree bark for quinine and coca leaves for cocaine for the Parke-Davis pharmaceutical company. He became Professor of Botany and Materia Medica at the College of Pharmacy at Columbia University in 1889.[326] He had a founding role and life-long association with the New York Botanical Garden (NYBG) that, in 2013, established the Henry Hurd Rusby Award for Excellence in Ethnobotany and Ethnomedicine. Rusby's initial publication of his experiments with radium fertilizer was a full-page, illustrated article in the *The New York Times* on October 14, 1914 that was followed by a lecture to the NYBG on November 14, 1914 and a two-part article in published in SCC's house journal *Radium*.[327] Rusby reviewed previous work in America and Europe on the effects of radium on plant growth dating from 1908 and concluded that while the studies indicated high levels of exposure to radium were "toxic" to plant life, small amounts were "healthfully stimulating." He thought that overall the results called for more testing — by him.

Rusby's experiments began with a winter culture of radishes in a greenhouse and with seedlings in window boxes in his home. The studies were then scaled-up, with field crops grown at a farm in Northfield, Ohio, fruits and vegetables grown at "an experimental garden in Pittsburgh" (in fact, the garden of Joseph Flannery's home), and a 1.5-acre plot in Nutley, New Jersey. Rusby's crops included radishes, potatoes, celery, various beans, parsnips, peas, onions, peppers, cucumbers, tomatoes, carrots, eggplants, various melons, corn, spinach, squash, cabbage, and pumpkins. He reported:

> "[T]he yield of most crops can be increased by the addition of some amount of [radium fertilizer], the amounts differing with different crops. The beneficial effects continue over successive crops, probably for several years. The largest amount required by any crop would cost less than the increased market value of such crop of the first year...Radium is not a plant food. The necessity for fertilizer is but little decreased by its use. The fertility of unused ground will spontaneously increase at a much greater rate when treated with radium" (figures 7.4 - 7.6).[328]

In January 1915, the University of Illinois Agricultural Experiment Station issued a report by Hopkins and Sachs on their studies. They rebutted Rusby's claims having found that natural variations, rather than the radium, may have caused the differences that Rusby reported and noting that in some cases the increases reported by Rusby were "found only by selecting the highest results from rather discordant data." They concluded that the "well-informed farmer on the common Illinois land…will not waste his money on so-called 'complete' fertilizers, nor on new advertised soil or crop stimulants."

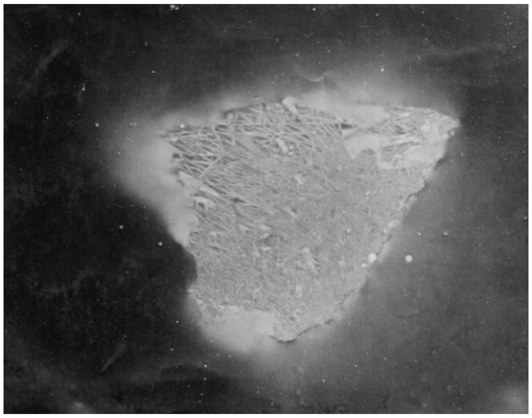
Nonetheless, SCC could not have asked for a more favorable and more public endorsement of its fertilizer than Rusby's article in the *The New York Times*. It was followed in 1915 by a blitz of radium fertilizer advertisements in American horticultural and gardening magazines, e.g. *House and Garden, The Garden Magazine, The Florists Review, Country Life in America*, and *Good Housekeeping* Magazine (figure 7.7).[329] On April 16, 1915, SCC announced it would annually ship 75,000 tons of the radium-infused fertilizer, the tonnage representing a standard brand of commercial fertilizer to which tailings were added.[330] The product, labeled "Radium Brand Fertilizer," was promoted by another SCC subsidiary, Radium Fertilizer Company.

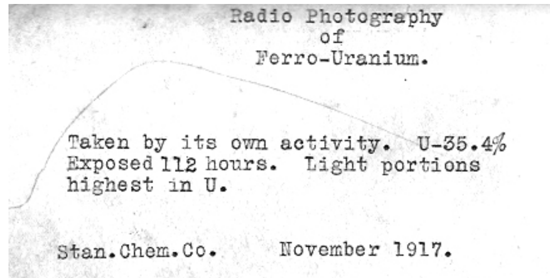
The disagreement regarding the value of fertilizer continued. In April 1915, Rusby republished his conclusions in *Scientific American Supplement* that was followed by rebuttals by Hopkins and Sachs in *Science* in May.[331] Then, in August R. R. Ramsey, an Associate Professor of Physics, at Indiana University, weighed in pointing out the amount of radium added to soil by the fertilizer was miniscule relative to the amount of radium naturally present in soil.[332] In October, editors of the *Journal of the American Medical Association* joined the debate. After summarizing the work of Rusby, Hopkins and Sachs, and Ramsey, the editors concluded, "It may be that eventually some means will be found by which radium can be utilized in practical agriculture. At present, however, the best evidence we have does not encourage us to regard this as an immediate possibility."[333]

At least one commercial nursery in Canonsburg was a customer. Many years later, during the remediation of the SCC Canonsburg plant site, state and federal officials identified the former nursery as one of 163 off-site locations where contaminated materials traceable to the site had to be removed. James G. Yusko, the state regional health physicist overseeing the cleanup, recalled in a conversation with Joel Lubenau that while inspecting the former nursery property he was able to trace the boundaries of the growing beds with his radiation survey meter.

One more use was found for the tailings. A member of the Canonsburg town council who was employed by SCC offered the mill tailings to the town for filling street potholes and grading unimproved streets. The material was determined to be suitable for this purpose and it was obtained for the cost of hauling. Years later, the local newspaper published a history of the Canonsburg plant headlining it, "Canonsburg Once Scene of World's Great Supply of Radium, Street Paved With Discarded Residue."[334] This led to local quips that Canonsburg's streets were paved with radium. The fill was later recovered to extract the vanadium and uranium but the tailings from that process were, like the original tailings, radioactive.

While there was a viable market for the vanadium byproduct of the Canonsburg mill, the market for uranium remained limited during Flannery's lifetime.[335] A great demand for uranium would develop for the production of nuclear energy and weapons — but that was 20 years in the future. The mill tailings were marginally marketable — in part because their radioactivity was thought to be advantageous for fertilizer and in part because their large volume made them useful for fill. In time the tailings would prove to be an environmental and public health hazard.





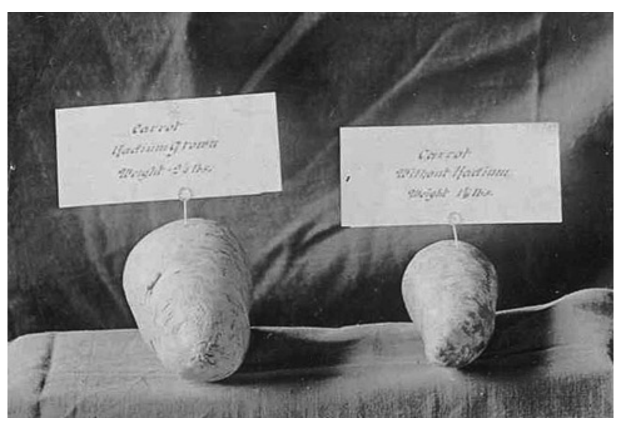
Radio Photography
of
Ferro-Uranium.

Taken by its own activity. U-35.4%
Exposed 112 hours. Light portions
highest in U.

Stan.Chem.Co. November 1917.

7.1, 7.2 Autoradiograph of ferro-uranium alloy and the exposure specifications. *HHC3*

7.3 Henry H. Rusby, MD, Dean of the College of Pharmacy of Columbia University. *NYBG*



7.4, 7.5 Radium fertilizer's reportedly beneficial effect on the growth of potatoes and carrots. *ORAU*

7.6 The taller flowers received radium fertilizer. *ORAU*

7.7 July 1915 advertisement for Radium Fertilizer brand plant food in *Good Housekeeping Magazine*. *NMNSH*

Chapter 8: Radium City[336]

"A remarkable exhibition of the ascendency of the technical and scientific mind over the frail and weary body."

In 1913, SCC's first year of commercial production, it produced 2.1 grams of radium.[337] Because domestic demand was limited, most of it was exported. In his Congressional testimony, Flannery projected SCC's annual production would increase to 15 grams and that SCC had contracts for all of 1914's expected output.[338] The assassination of Austrian Archduke Franz Ferdinand by Gavrilo Princip, a Bosnian Serb, on June 28, 1914 changed that. Austria-Hungary declared war on Serbia on July 28th. Within days the war involved all of the major European powers and grew to include Japan. European demand for U. S. radium vanished, and with it, SCC's rosy prospects for the future. Production for 1914 was only 9.6 grams and the following years was even less; 1.7 grams in 1915 and 5.0 grams in 1916.[339]

In 1917, production rose to 7.0 grams because of a new use of radium, luminous paint for military purposes.[340] Concentrated radium salts are self-luminous. The intensity of the glow relative to the quantity of radium required to make it visible was such that commercial application was not economical. Scientists soon discovered that mixing radium salts with certain substances made them fluoresce, in particular, zinc sulfide. In 1903, George F, Kunz, gemologist for Tiffany & Company, and a City College of New York chemist, Charles Baskerville, developed luminous paint by mixing radium-barium salt, zinc sulfide, and linseed oil.[341] Commercial applications were limited until World War I when the U.S. military wanted luminous paint for night warfare. Luminous painting of the dials and indicators of instruments on the bridges of naval vessels and in airplane cockpits made them visible without having to use external light sources and without impairing night vision. The infantry used the paint to illuminate watches, compasses, and gun sights and to illuminate troop routes. In 1917, SCC organized a subsidiary, Radium Dial Company, to manufacture and market luminous paints and painted products; ninety-five percent of SCC's radium production went into luminous paint.[342]

After the end of the war in 1918, demand for radium remained robust even though military demand for luminous paint vanished because a growing domestic market for the product for watches and clocks replaced it. Also, Flannery's innovative business model —– integrating production of radium with medical radium research and a smart marketing approach —– began paying off as a domestic market for medical radium grew. Production in 1918 was 13.6 grams; in 1919, 11.8 grams; and in 1920, 18.5 grams, exceeding Flannery's 1914 projection that SCC would produce 15 grams annually.[343]

With SCC prospering, Flannery turned his attention to another business venture. During World War I French aviators discovered the best gasoline for their engines was an intermediate weight variety.[344] The news drew the interest of chemist Martin André Rosanoff (figure 8.1). After a career that included heading the Chemistry Department at Clark University in Worcester, Massachusetts, he came to Pittsburgh, joining the faculty of the Mellon Institute of Industrial Research (now Carnegie Mellon University) where he explored methods of producing gasoline.[345] While at Clark, Rosanoff patented a simplified method of distilling products such as gasoline from oil that was cheaper and faster than traditional methods. After his move to the Mellon Institute Rosanoff approached Flannery for financial support.[346] Flannery agreed and became president of the Rosanoff Production Company. Early in 1918, the Army Signal Corps asked Rosanoff for samples of the gasoline that he was making. Tests by the National Bureau of Standards showed it to have a marked performance advantage at high altitudes over the fuel then in use, and the NBS recommended the Army shift to this gasoline. In July 1918, the Signal Corps made the development of this new aviation fuel a top-priority project. Construction began on a production plant at the Mellon Institute under Rosanoff's supervision. Mellon students on the project were given draft exemptions and uniformed troops having specialized skills needed at the plant were assigned by the Signal Corps to work there.[347] The war's end in November 1918 ended government interest in the project but Flannery felt there was a domestic market for the new fuel.[348]

In 1919 Flannery was in declining health. His physicians had urged him to go to California for a much-needed rest which he promised to do after a trip to New York City for discussions to finance the Rosanoff process. While there he was taken ill.[349] He was able to return home but did not recover. On January 18, 1920 Joseph M. Flannery died in his home in Pittsburgh.[350] His death was widely noted and much lamented in Pittsburgh, especially in the city's business circles, where he was greatly admired.[351] He left his wife, Mollie Gearing, sons Joseph Michael, Jr., John Gearing, and Raymond Girard, and a daughter, Helen Kirwin.

Six weeks later, Pittsburgh's business community suffered another shock when on March 6, 1920 James J. Flannery died.[352] He had been seriously ill for a year but his health had been permanently damaged years earlier when he visited the vanadium ore deposits in Peru and struggled with the high altitude.[353] The death of his brother to whom he was close may have been a final blow. His wife, Harriet Rogers and nine children survived him.

The SCC board elected James C. Gray to succeed Joseph Flannery as company president (figure 8.2).[354] Gray, an attorney, had been associated with the Flannery brothers since their organization of the Flannery Bolt Company. [355] He came to Pittsburgh after attending Ohio State University and was admitted into law practice in Columbus, Ohio. In Pittsburgh, he worked in the legal and auditing departments of the Pennsylvania Railroad and then entered private practice in Pittsburgh and served in the city solicitor's office. He helped organize the Pittsburgh Law School which later became part of the University of Pittsburgh and became its Vice-Dean. One of his first tasks as president was serving as the gracious host when Marie Curie visited SCC.

* * *

On the morning of May 4, 1921 Marie Curie departed Le Havre France for America on the White Star liner RMS Olympi*c* (figure 8.3) to accept a gift of a gram of radium from the women of America. She was accompanied by her daughters, Irene and Eve, and by the driving force behind Curie's visit, Mrs. ("Missy") Marie Mattingly Meloney Brown. Brown, an American journalist had repeatedly asked to interview Marie Curie. Finally, Mme. Curie consented and, in May 1920, Brown met Curie in her laboratory in Paris.[356]

Brown was a seasoned journalist. She began working at 17 at the *Washington Post*, moved to *Everybody's* as associate editor, and then became editor of the *Delineator,* a women's issues magazine.[357] In 1923, in her introduction to Marie Curie's biography of Pierre Curie, Brown recalled that prior to meeting Marie Curie she had met Thomas Edison in his laboratory and was impressed by how well equipped it was. As a child she remembered living near Alexander Graham Bell in Washington DC and how much she admired his large house and fine horses.[358] She also knew that large amounts of money had been spent on radium luminous paints for military gun sights and watches. These recollections colored her expectations when meeting Marie Curie in May 1920. Instead, "I found a simple woman, working in an inadequate laboratory and living in an inexpensive apartment, on the meager pay of a French professor."[359]

On meeting Curie, she recalled, "Suddenly I felt like an intruder. I was struck dumb. My timidity exceeded her own. I had been a trained interrogator for twenty years, but I could not ask a single question of this gentle woman in a black cotton dress."[360] Mme. Curie began the conversation by speaking how fortunate America was in having so much radium, fifty grams, rattling off the names of American cities and the quantities of radium in each. Brown asked the obvious question, how much had she? Mme. Curie's reply was that she had none. What there was belonged to the laboratory; it was barely more than a gram and most of it was dedicated to medical purposes. Mme. Curie recounted the decision that she and Pierre made to not patent their discovery of radium. "We were working in the interests of science. Radium is an element. It belongs to all people."[361] To enable her research, more radium was needed — another gram, "But, I cannot buy it, radium is too dear for me."[362]

From that interview emerged a plan by Brown to secure a gram of radium for Mme. Curie, to be paid for by the women of America. Two committees were organized, a women's committee to raise money and an advisory committee.[363] Mme. Curie had nothing to do with the fund raising, but when it was completed, Brown prevailed upon her to come to America to accept the gift in a presentation at the White House by President Warren G. Harding. Her itinerary was expanded to six and one-half weeks in America to allow time to visit American education, research, government and industrial institutions of which many wished to bestow honors on her. For her own part, she asked only to visit to the Grand Canyon, Niagara Falls, and Pittsburgh because "it is the place where the greatest amount of radium in the world is produced."[364]

Marie Curie's itinerary was full and tightly scheduled calling for 30 stops in towns and cities in 46 days, with only one day set aside for rest.[365] She was 53 years old and suffered from low blood pressure, dizziness, and anemia, problems that affected her stamina. Because she was frequently fatigued by the demands of the schedule planned events would have to be curtailed, postponed, or cancelled.

The Olympic docked in New York City on May 11th (figure 8.4). Marie Curie's voyage on the Olympic was her first transatlantic trip. She had been "frightfully seasick," and after the ship had docked, had to rest in her cabin for two hours before she felt well enough to meet the press and face a battery of photographers and movie-news cameramen.[366] Afterwards, Mrs. Andrew Carnegie hosted a lunch for her at the family residence on the corner of Fifth Avenue and 91st Street.[367] The Carnegie-Curie connection dated to 1905 when Andrew Carnegie provided a grant to American radium physicist William Duane to continue his studies with Pierre and Marie Curie.[368] In 1907 Carnegie placed at the disposal of the Curie laboratory in Paris $50,000 for fellowships and research to support up to six researchers annually.[369]

Her first visits were to three women's colleges — Smith College, which bestowed its first honorary Doctor of Science degree on Curie, (figure 8.5)[370] and Mt. Holyoke College,[371] both in Massachusetts, and Vassar College in New York.[372] At Vassar College, she made her only lengthy public address in the U.S. It became noteworthy for its concluding message to the student body: "It is my earnest desire that some of you should carry on this scientific work and keep for your ambition the determination to make a permanent contribution to science."[373]

She returned to New York City for three days filled with events honoring her, highlighted by a reception held Wednesday, May 18th by the Association of American University Women at Carnegie Hall where 3,500 members crowded into the hall to honor her. It was the largest audience assembled for Curie during her visit to America.[374] She left New York City by train for Washington DC shortly after midnight, arriving in the nation's capital on Friday, May 20 at 6:30 AM where a reception committee welcomed her. That afternoon, at 4 PM President Harding presented her a Certificate of Gift of the gram of radium at the White House (figures 8.6-8.9).[375]

Her long tiring day was not yet over; that evening, there was a 9 PM reception in her honor at the U.S. National Museum (today the Smithsonian National Museum of Natural History).[376] Nevertheless, she kept her engagements the following days in Washington visiting government laboratories and attending official functions.[377] She was to leave Washington at 9 AM on May 23rd for Philadelphia to attend a 1 PM luncheon and visit Women's Medical College of Pennsylvania (WMCP) to receive an honorary Doctor of Medicine. Her schedule for the rest of the day called for a late afternoon visit to the University of Pennsylvania to receive another honorary degree, followed that evening by a ceremony at the College of Physicians of Philadelphia. Instead, finding herself badly fatigued, she delayed her departure from Washington and sent her daughters ahead to accept the honorary degrees on her behalf.[378]

Marie Curie arrived in Philadelphia in time to attend the College of Physicians of Philadelphia meeting where she donated an historic piezo-electrometer to the college. Piezo-electrometers were specialized pieces of laboratory equipment that had been invented by Pierre Curie and his brother, Jacques.[379] The donated electrometer had been made by Pierre Curie and used by Pierre and Marie Curie in their studies leading to the discoveries of polonium and radium (figures 8.10 & 8.11).[380] The next day, May 24th, was an especially long one. First, she amended her schedule to stop by the WMCP to thank Dean Dr. Martha Tracy for its honorary degree, (figure 8.12), and then spent the afternoon at the Welsbach Company in Gloucester City, New Jersey which produced mesothorium (radium-224, another isotope of radium). That evening she was a guest of the American Philosophical Society which inducted her as a member and awarded her the John Scott Medal.[381] Finally, at 11:10 PM she and her party boarded a Pennsylvania Railroad train to Pittsburgh. On the morning of the 25th, Marie Curie arrived in Pittsburgh — utterly exhausted.

First newspaper reports were dire — that because of her ill health and weariness, her trips to the SCC plants in Canonsburg and Pittsburgh would be cancelled, as well as her planned tour of the western United States.[382] During her time in Pittsburgh she stayed at the estate of Mrs. Henry R. Rea in Sewickley, an upscale suburb west of Pittsburgh. The pleasant surroundings had a beneficial effect while she rested there.[383] As a result, the convocation planned by the University of Pittsburgh to confer an honorary Doctor of Laws remained on her schedule for Thursday, May 26th, (figure 8.13) but the ceremony was shortened to fifteen minutes to conserve her energy.[384] It was there that William J. Holland, Director of the Carnegie Institute, remarked: "We are in the habit of speaking of Pittsburgh as 'The Iron City.' We sometimes call it 'The Steel City.' It may also justly called 'The Radium City.' "[385]

Prior to the convocation, Curie visited SCC's radium laboratories in the Vanadium Building.[386] Reporters noticed that during her one and half hour visit "among retorts and test tubes, she seemed to forget her weariness."[387] It happened again the following day when she visited SCC's plant in Canonsburg accompanied by James C. Gray, SCC president, and Louis F. Vogt, plant manager. A *Pittsburgh Sun* reporter described her visit:

> Between vast tanks, containing 27 tank-carloads of muriatic acid, past steaming press filtration rooms, where fumes rising from the liquid almost gag one, in the carbonating department where the raw ore is treated in a soda ash wash; even in the smelter room where a cupola of vanadium by-product was tapped into ladles, Mme. Curie seemed strangely in place. Bareheaded, with wisps of gray hair blowing about her anxiously wrinkled forehead, dressed simply in black, Mme. Curie seemed entirely in her own element, as sh[e] has not appeared since coming to America. One could not help but realize how much more stimulating and satisfactory to her was the visit…than the many social and official functions which she has graciously attended. No pair of steps was too arduous, no tank of acid too malodorous, nor was the distance through the many buildings of the plant too long for this scientist, who came to the plant obviously a travel and reception-worn woman, seemingly too tired to walk even a short distance. After delving into every phase of the process, which would have tired a strong man were he not interested, Mme. Curie asked for a few moments with Mr. Vogt, who has been connected with the Standard Chemical Company since the start of the plant and knows more about radium extraction. At the end of 15 minutes, during which time the visiting scientist asked a multitude of questions and did a vast amount of figuring, she emerged fresh and radiant. It was a remarkable exhibition of the ascendency of the technical and scientific mind over the frail and weary body (figures 8.14-8.17).[388]

Marie Curie's visits to the Standard Chemical Company plants in Canonsburg and Pittsburgh became special moments for Louis Vogt and James Gray. Vogt, in addition to hosting Curie's visit to the Canonsburg plant, was invited by Pittsburgh's radio station KDKA to talk about radium in a special radio broadcast. This was a singular honor because KDKA was America's first commercial radio station having gone on the air just the previous year and was the flagship station of the Westinghouse Broadcasting System.[389]

For Gray his meeting Marie Curie would have been a poignant occasion because he was a cancer survivor who owed his life to radium. What thoughts went through Gray's mind as he gently supported the arm of this frail, grey-haired woman, the co-discoverer of the element that saved his life?

Marie Curie left Pittsburgh and went to Mrs. Brown's home in New York City to rest. Reporters were informed that her trip to the west coast was cancelled although she would travel as far west as the Grand Canyon to fulfill her wish to see it.[390] She was originally scheduled for just an overnight stopover at Grand Canyon, but her stay there was extended to allow for additional rest.[391]

After the Grand Canyon she traveled to Chicago where she received an honorary degree from the University of Chicago and the William Gibbs Medal from the American Chemical Society.[392] Her next stop was Buffalo, New York where she made her desired visit to the Niagara Falls but again, fell ill. Scheduled events in Buffalo were cancelled and she stayed at a friend's home to rest.[393]

On Saturday, June 18th, she arrived in Boston for the final segment of her trip. She was reportedly "tired but recovered from her recent indisposition.[394] In Cambridge, Harvard President A. Lawrence Lowell presided over a reception at the Sanders Theatre attended by a thousand students and contributors to the radium fund.[395] She then left for New Haven, Connecticut where Yale University conferred one more honorary degree.[396] From there, she travelled to New York City to return to France.

Before leaving America, Marie Curie held a final meeting with the press at the Mrs. Brown's home on June 24th in which she expressed her admiration for America's scenic attractions, cities, and colleges and universities and, in particular, Pittsburgh because of its radium production. Even so, she noted her frail health had prevented her from doing everything that had been planned:

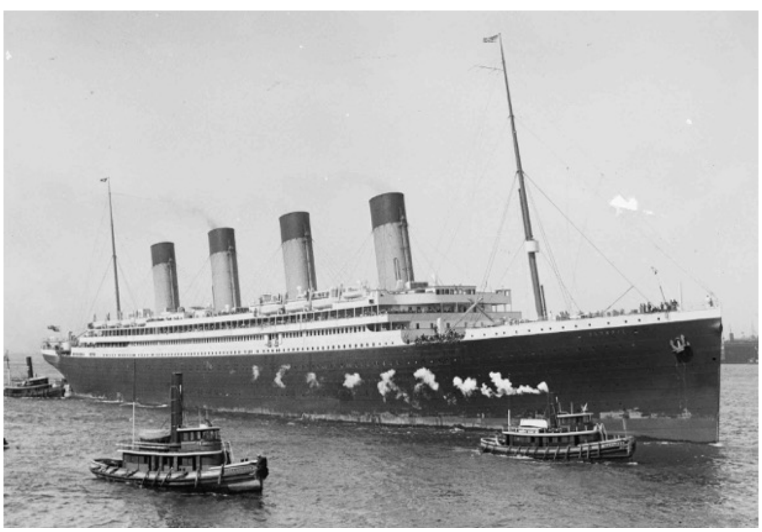
> It is with much regret, that I come to the last day of my visit to America. There has been only one disappointment that has been my physical inability to do all the things I would wish to do and to meet all the American people I much desire to meet. My work with radium, and especially during the war, has so damaged my health as to make it impossible for me to see many of the laboratories and colleges in which I have a genuine interest.[397]

After a bon voyage party, she sailed for France on the Olympic on Saturday, June 25th[398] and arrived in Cherbourg on July 2nd. Government officials and children carrying flowers greeted her while French police boarded the ship to take the radium to her laboratory in Paris.[399]

Subscriptions to the Marie Curie Radium Fund exceeded the $100,000 goal to pay for the gram of radium. However, SCC invoiced the Fund for only $65,656.50 (figure 8.18).[400] Part of the excess was used to purchase radium ore and other samples and the remainder was placed into a trust fund for Marie Curie. She had also received $6,884 in awards and an advance of $50,000 from an American publisher for a biography of Pierre Curie.[401] Not counting the value of the radium she so much desired, she had received a total of $116,841, the equivalent of $1,640,000 in 2018 dollars.[402] Another gift was her friendship with Mrs. Brown, one that endured until Curie’s death in 1934 (figure 8.19).

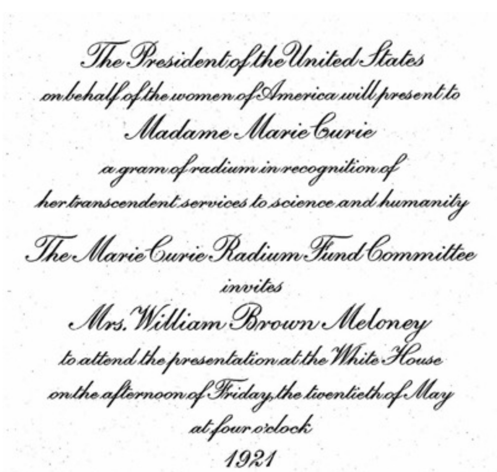
 

8.1 Left, Martin A. Rosanoff. *SHI1* 8.2 Right, James C. Gray. *CPP*

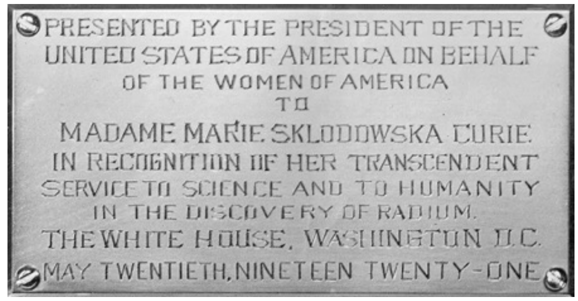
8.3 Left, the White Star Lines *Olympic,* a sister ship of the *Titanic. LOC* 8.4 Right, photographed onboard the Olympic after arrival in New York City on May 11 1921. From the left, standing, Eve Curie, Marie Meloney Bown, Irene Curie; sitting, Marie Curie. *LOC*

8.5 Madame Marie Curie and President Neilson at the Special Convocation in her honor, Smith College, May 13, 1921. Received SC.D. *SC*

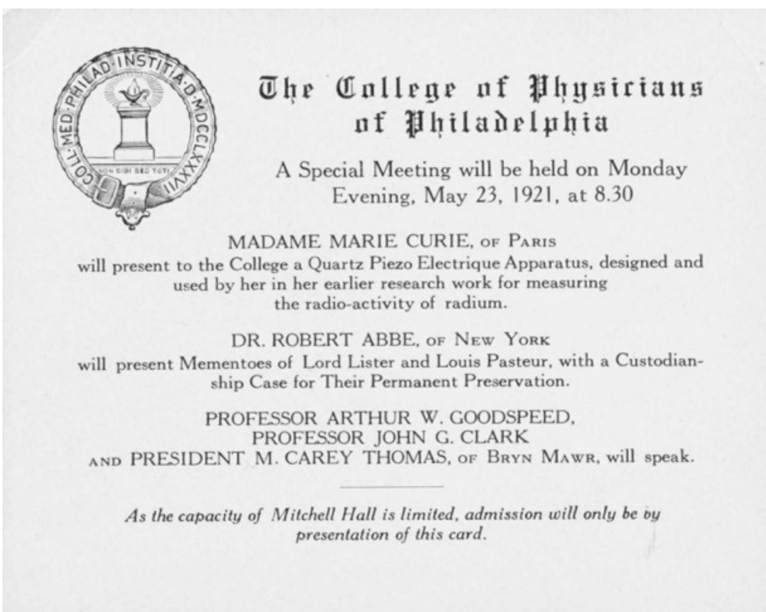


The President of the United States
on behalf of the women of America will present to
Madame Marie Curie
a gram of radium in recognition of
her transcendent services to science and humanity
The Marie Curie Radium Fund Committee
invites
Mrs. William Brown Meloney
to attend the presentation at the White House
on the afternoon of Friday, the twentieth of May
at four o'clock
1921

8.6 Left, the 1921 White House invitation to Mrs. Meloney Brown to attend the Marie Curie ceremony. *CU* 8.7 Right, May 20, 1921, Marie Curie, clutching the Certificate of Gift of the radium descending the White House steps with President Warren G. Harding. *LOC*



8.8, 8.9 The shipping cask for the ten glass tubes of radium, each containing 100 milligrams of radium (although replicas were used for the display at the White House) and the engraved plaque on the cask. *HHC3*



The College of Physicians of Philadelphia

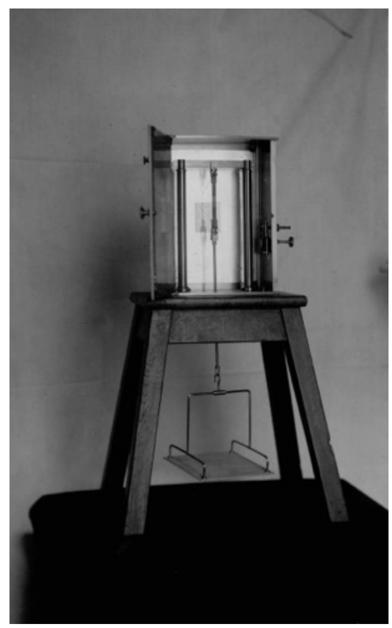
A Special Meeting will be held on Monday Evening, May 23, 1921, at 8.30

MADAME MARIE CURIE, OF PARIS will present to the College a Quartz Piezo Electrique Apparatus, designed and used by her in her earlier research work for measuring the radio-activity of radium.

DR. ROBERT ABBE, OF NEW YORK will present Mementoes of Lord Lister and Louis Pasteur, with a Custodianship Case for Their Permanent Preservation.

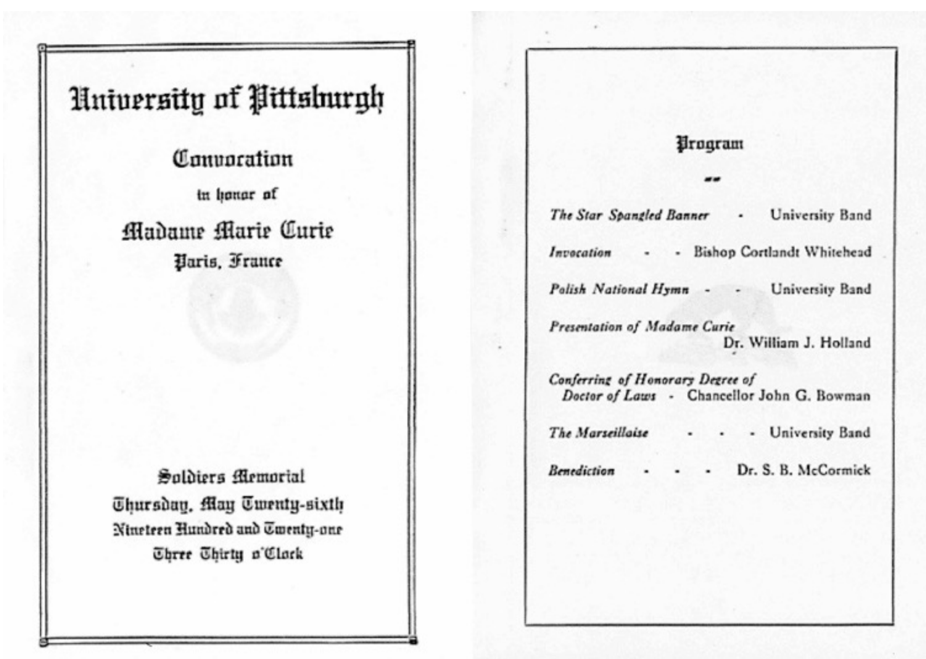
PROFESSOR ARTHUR W. GOODSPEED, PROFESSOR JOHN G. CLARK AND PRESIDENT M. CAREY THOMAS, OF BRYN MAWR, will speak.

As the capacity of Mitchell Hall is limited, admission will only be by presentation of this card.



8.10, 8.11 The College of Physicians of Philadelphia invitation card for the Marie Curie reception, May 23 1921 and the piezo-electrometer, hand-crafted by Pierre Curie and used by Pierre and Marie Curie in their discovery of radium, that Marie Curie presented to the College of Physicians of Philadelphia on May 23, 1921. *CPP*

8.12 Women's Medical College of Pennsylvania Dean Martha Tracy and Marie Curie, May 24, 1921. *DU*



University of Pittsburgh

Convocation

in honor of

Madame Marie Curie

Paris, France

Soldiers Memorial

Thursday, May Twenty-sixth

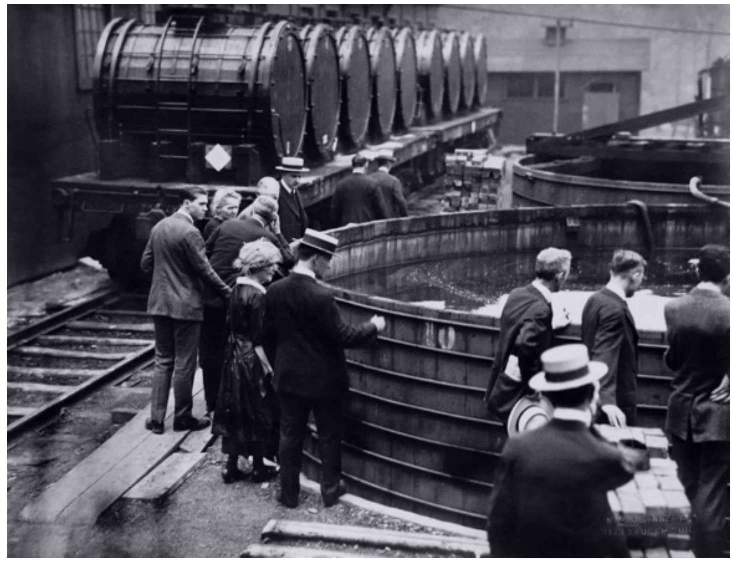
Nineteen Hundred and Twenty-one

Three Thirty o'Clock

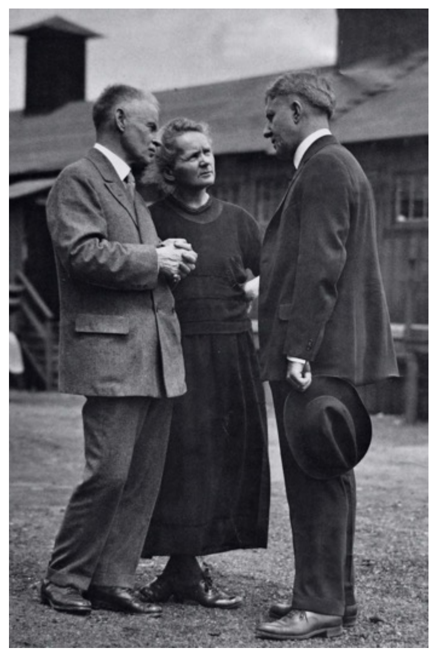
Program

The Star Spangled Banner	University Band
Invocation	Bishop Cortlandt Whitehead
Polish National Hymn	University Band
Presentation of Madame Curie	Dr. William J. Holland
Conferring of Honorary Degree of Doctor of Laws	Chancellor John G. Bowman
The Marseillaise	University Band
Benediction	Dr. S. B. McCormick

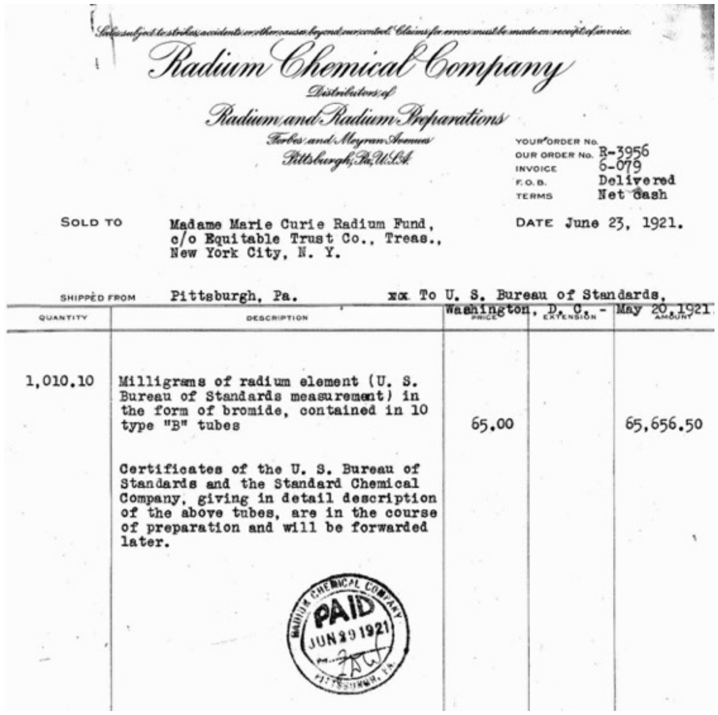
8.13 Program for the May 26, 1921 University of Pittsburgh Convocation to confer an Honorary Degree of Doctor of Laws. *HHC5*

8.14 Left, in this widely published photograph of her visit to the SCC Canonsburg plant, a visibly frail Marie Curie leans on the arm of SCC president James Gray. Mill manager Louis Vogt is facing her. In the doorway on the right, is Joseph Flannery, Jr., son of the company's founder. *HHC3* 8.15 Right, Marie Curie pauses at the outdoor tanks. Facing her is Louis Vogt whose head partially obscures that of James Gray. To the left of them is Joseph Flannery, Jr. *HHC3*

8.16 Left, a rare photograph of Marie Curie: she is smiling, perhaps enjoying a laugh while on the arm of James Gray who follows Louis Vogt. In the doorway is Wallace Lyle, Canonsburg process chief. *HHC3* 8.17 Right, at the visit's end, a few more moments of conversation. Left to right, Gray, Curie and Vogt. *HHC3*



Sales subject to strikes, accidents or other causes beyond our control. Claims for errors must be made on receipt of invoice.

Radium Chemical Company

Distributors of

Radium and Radium Preparations

Forbes and Meyran Avenues

Pittsburgh, Pa. U.S.A.

YOUR ORDER No.
OUR ORDER No. R-3956
INVOICE 6-079
F.O.B. Delivered
TERMS Net Cash

SOLD TO Madame Marie Curie Radium Fund,
c/o Equitable Trust Co., Treas.,
New York City, N. Y.

DATE June 23, 1921.

SHIPPED FROM Pittsburgh, Pa. xx To U. S. Bureau of Standards, Washington, D. C. - May 20, 1921.

QUANTITY	DESCRIPTION	PRICE	EXTENSION	AMOUNT
1,010.10	Milligrams of radium element (U. S. Bureau of Standards measurement) in the form of bromide, contained in 10 type "B" tubes	65.00		65,656.50
	Certificates of the U. S. Bureau of Standards and the Standard Chemical Company, giving in detail description of the above tubes, are in the course of preparation and will be forwarded later.			

RADIUM CHEMICAL COMPANY
PAID
JUN 29 1921
PITTSBURGH, PA.

8.18 Radium Chemical Company's June 25, 1921 invoice to the Madame Marie Curie Radium Fund for the gram of radium given to Marie Curie. Although Standard Chemical Company bid $100,000 for the contract the company chose to eschew any profit, charging only for the cost of the production. *CU*

8.19 A formal portrait of Marie Meloney Brown and Marie Curie. *CU*

Chapter 9: Radium Dangers

"I hope you get paid well for the chances you take."

Marie Curie's disclosure in her American press conference that her fragile health was caused in part to her work with radium was a rare public admission on her part. Marie and Pierre Curie suffered injuries to their hands from handling radium sources early in their careers, as did other radium scientists. But the full extent of the damage caused by radium was not immediately apparent. In addition to radiation from radium sources, there were dangers from radium inside the body and their long-term health effects would become apparent only with the passage of time. It would be a learning experience for the Curies and other radium scientists. It would also be a learning experience for SCC workers.

* * *

Roentgen's discovery of x-rays was first reported in newspapers and journals beginning January 5, 1896.[403] Later that month, Dr. E. H. Grubbe, experimenting with x-rays, suffered an x-ray burn on his hand.[404] In March 1896, Thomas Edison reported irritation of his eyes from x-rays and cautioned against continuing their use.[405] Out of concern for himself and his workers, he abandoned work with x-rays although this was too late to prevent the death in 1904 of one of his assistants, Clarence M. Dally, as a result of his x-ray exposure.[406] Scientists soon discovered that radium also caused burns. The earliest reports came in October 1900 from German scientists, Friedrich Walkoff and Friedrich Giesel.[407] In April 1901, to test these reports, Pierre Curie deliberately exposed his arm to a radium source for several hours resulting in a burn that took several months to heal (figure 9.1).[408] French scientist Henri Becquerel accidentally inflicted a burn by carrying a radium source in a jacket pocket multiple times. Afterwards, in telling of his experience to the Curies, he remarked about radium, "I love it, but I owe it a grudge!"[409] In 1901 Becquerel and Pierre Curie reported that Marie Curie had suffered a blister and reddening of the skin after carrying a box containing radioactive material. Their own hands had been affected — specifically desquamation (peeling) of the skin, inflammation, and painful hardening of the skin and, in the case of "one of us," the inflammation of the extremities lasted fifteen days, followed by loss of skin, and chronic pain.[410] That person was not identified, but most likely was Pierre Curie.

On June 25, 1903, Marie Curie successfully defended her doctoral thesis and received a Doctor of Physical Science from the University of Paris *très honorable.* By chance, Ernest Rutherford was in Paris. He missed the ceremony at the university but was invited to a dinner party that evening in honor of Marie Curie that was arranged by Paul Langevin, a long-time colleague and friend of Rutherford and the Curies. The celebratory dinner was a great success and, about 11 PM, the party went to the garden to enjoy the evening. At that point, Pierre Curie, who had kept hidden a small tube of radium mixed with zinc sulfide, brought it out.

> In the darkness as the tube emerged, the zinc coating suddenly luminesced with a brilliant glow caused by the radium. Each one watched silently, and each one was impressed.

But in the light from the tube Rutherford saw something else. He noticed Pierre Curie's hands were raw and inflamed. It even seemed painful for Curie to handle the tube.[411] The following day, in writing a letter, Pierre Curie asked the recipient to excuse his handwriting because fingers had become so painful it was difficult to hold the pen.[412]

The 1905 death of Jules Rhens in France was one of the earliest deaths, if not the first, attributed to radium.[413] The cause was a severe burn suffered as a result of transporting inadequately shielded radium. When SCC embarked on commercial production of radium in January 1913, formal radiation protection guidance and standards for handling radium did not exist, and its scientists had to learn of the dangers of radium mainly through self-discovery — injuries they themselves suffered. In time, anecdotal accounts by other workers that came to their attention and reports of injuries published in scientific and medical journals added to their knowledge.

An early example of SCC's naive practices occurred in 1913 when SCC sold 500 milligrams of radium to Great Britain for hospital use. Otto Brill personally delivered the radium, carrying it in his vest pocket when leaving Pennsylvania.[414] Carrying 500 milligrams of radium this way would have risked injury even if carried only for a short period of time. Perhaps Brill was injured because later that year when another shipment was made overseas, it was handled differently. On that occasion SCC, prepared 250 milligrams of radium to be sent to Brill who had returned to Austria. Since the radium was deemed too valuable to be sent by mail (which was allowable at the time), SCC sent the radium via a messenger, an employee. The radium was contained in a wrapper small enough to be again carried in a vest pocket but this was now considered unsafe. So, "it was tucked carefully away in a corner of a suitcase."[415] Given the apparent absence of any significant shielding and assuming the suitcase had been carried by the messenger and kept in his stateroom while crossing the Atlantic, this improvement in radiation protection was an incremental one at best.

The following year saw a much larger overseas delivery of radium. SCC tasked a chemist, Glenn Donald Kammer, with delivering four grams of radium, valued at almost half a million dollars, to England. On August 1, 1914 he sailed for England carrying the shipment in a valise (figure 9.2). It was similar to the medical valises carried by physicians when they made house calls. The amount of shielding would have been minimal because otherwise it would have been too heavy to carry. Given the value of its contents, the valise should have been checked with the ship's purser for safekeeping but it is not certain Kammer did this. If, instead, he stowed the valise in his stateroom, he would have received additional radiation exposure.

While in England Kammer wrote to Viol informing him of his technical discussions with English scientists. He also conveyed warnings from them about the radiation exposures of himself, Viol, and others at SCC:

> Let Miller [Arthur L. Miller, Viol's assistant] weigh some of the tubes as you will expose yourself too much. They held up their hands in horror here when I told them what I have done with radium. Marsden [Rutherford's associate] said "You have done a life's work." A Radium Institute man warned 'watch out in four or five years from now' and Doctor

Robeson, an x-ray man from Northampton, commented, "I hope you get paid well for the chances you take."[416]

Meanwhile, in June 1914, SCC published in its house journal *Radium* a summary of a report from the Radium Institute for Biologic-Therapeutic Research in Berlin of twelve cases of occupational injuries from working with radioactive substances for "long periods." Injuries included changes in blood parameters and damage to the skin of fingertips.[417] With respect to skin changes, the authors speculated they might lead to permanent injuries similar to those seen in x-ray burns and concluded:

> For this reason severe burns are to be carefully avoided, and apparatus for use in the application of radium should be designed with a view to requiring the least possible handling in the course of preparation for use on the patient. Long pincers should be used whenever possible instead of grasping the tube or preparation with the fingers. In factories the general disturbances may be avoided by: 1. Very good ventilation to remove the emanation [radon]; 2. Protecting the body by using metal plates on the tables to absorb the rays; 3. Short working hours and frequent vacations or change of occupation; 4. Repeated and careful observation by a physician, especially of the blood picture, which should be observed at least twice a year.[418]

In March 1916 *Radium* reprinted an illustrated article by Dr. Thomas Ordway on occupational injuries caused by radium that was originally published in the *Journal of the American Medical Association.*[419] Ordway recounted his observations of the precautions taken and the injuries he saw while he was in London, Vienna, and Germany for clinical studies. He then presented details of cases observed at the Huntington Hospital in Boston, accompanied by illustrations of the injuries, and commented:

> From this it will be seen that injurious local effects were anticipated so that the changes to be described were not acquitted unwittingly but in spite of precaution. The increasing use of large quantities of radium warrants a detailed description and record of these changes not only because of the annoyance and discomfiture caused, but also as a warning from analogy to the Roentgen ray of more serious late effects such as atrophy, intractable ulceration and even cancer. Already in certain instances there have been caused not only great annoyance from discomfit but actual impairment in performing delicate manipulations because of the persistent local anesthetic effects....These symptoms occurred very insidiously, and consisted of blunting of the finger-tips, parathesia, such as increased sensitivity to heat and pressure, amounting at times to actual pain, and anesthesia of varying degrees….Each assistant and nurse before engaging in the clinical application of radium was warned of the annoying and possible dangerous effects, and told not to handle the active tubes of emanation [radon] with the fingers but to make use of forceps. In spite of this, a certain amount of handling was unavoidable in changing the radium tubes for suitable filtration and protection in difficult cases (figure 9.3).[420]

The Boston hospital devised forceps and special vises to minimize contact of fingers with sources, added shielding, and instituted special procedures to minimize exposure. Other changes were shortening staff's work hours, periodically rotating them to other duties, and for those involved in preparation and use of radon sources, improving ventilation of their workplace. Periodic physical examinations with emphasis on blood work were instituted.[421]

In summary, Ordway found that while *acute* reactions to radium were well known, e.g. burns, intermittent exposures over a prolonged period caused late health effects, a significant finding.

Ordway's article in *Radium* was followed by an article by Viol describing forceps he designed for handling radium tubes to reduce exposures of the fingertips.[422] But the article's most interesting aspect was Viol's account of SCC's earliest radiation safety practices and the reasons for them (or their lack) that echoed Ordway:

> The writer has had occasion to handle radium tubes very frequently in the past three years. In this time about fourteen grams of radium have been produced in the Radium Research Laboratory of the Standard Chemical Company and most of the radium has been supplied in tubes and applicators for radium therapy. At the outset little information was available as to methods for handling the material and with a realization of the great value of the material being handled and with no exact idea of the dangers involved, *it was the custom at first to handle the tubes with the bare hand*s [emphasis added]. This was soon found to be disastrous, resulting in the production of typical radium burns on the ends of thumbs and forefingers.[423]

At SCC, one of the most hazardous procedures to workers' hands was "tubing" — the filling of capsules (tubes) with radium salt (figure 5.10). After sealing them, they were assayed. This was another hazardous process because the measurements required additional handling of the sources.

With respect to the value of using forceps, Viol estimated that when handling a capsule with bare fingers the radium is less than half a millimeter from the skin, the thickness of the capsule wall. If the source is moved five hundred millimeters from the skin, the source is one thousand times distant from the skin and the intensity reduced by a factor of one million.[424†] Viol's forceps helped reduce radiation exposure of the fingers, but even when using the forceps, the tips of the fingers were still in close proximity with the radium salt (figures 9.4 & 9.5). Viol reported that since instituting use of the modified forceps in late 1913, 500 glass capsules

† Viol's calculation was based on the "Inverse Square Law." Increasing the distance from a radiation source reduces the radiation exposure. The reduction factor is the inverse of the *square* of the increase. Increasing the distance by a factor of 2 reduces the exposure by the inverse of 2 times 2 -— one-forth. Increasing the distance by another factor of two reduces the exposure by the inverse of 2 times 2 times 2 — one-eighth. Viol's forceps increased the distance by a factor of 1000 so the exposure reduction was the inverse of 1000 times 1000 — one-millionth.

containing radium were handled repeatedly with only one incident of breakage that occurred when an inexperienced assistant handled a source.

In 1921, in the lead article in the July-August issue of *Radium*, SCC summarized what was known about the dangers of radium and x-rays.[425] Note was taken of the deaths of three workers at the London Radium Institute, in 1916, 1920 and 1921 respectively. Only the first was directly attributable to a disease associated with radiation exposure (pernicious anemia). Infective endocarditis and acute pneumonia were the causes of the other deaths but the institute's medical committee felt it probable that the workers' radiation exposures had weakened their resistance to the diseases. A study was made of the blood of every worker at the Institute "from the superintendent down to the hall porters." The study found exposure to radium resulted in changes in red and white blood cell counts that correlated with their exposure to radium. Additional measures to protect workers from exposure were put in place with the result that a year later, blood conditions were generally returning to normal. Experimental exposures of rats to increasing amounts of radiation from radium was found to result in reductions of the production of red blood cells, findings that confirmed the view that the effects found among radium workers were caused by exposure to radium. [426] Reports from the Radium Institute in Paris, the Cancer Commission of Harvard University, the Howard A. Kelly Hospital in Baltimore, and the Mayo Clinic, also confirmed the dangers of handling radium were avoidable with proper precautions.[427]

The article concluded with a reprint of a preliminary report of *The X-ray and Radium Protection Committee*, an English committee of experts convened for the express purpose of assessing the state of knowledge of the dangers of x-rays and radium, and issuing recommendations. Published in July 1921, the Committee report stated, in part:

> The danger of over exposure to x-rays and radium can be avoided by the provision of efficient protection and suitable working conditions. The known effects on the operator to be guarded against are: (1) Visible injuries to the superficial tissues which may result in permanent damage. (2) Derangements of the internal organs and changes in the blood. The following precautions are recommended:
>
> 1. Not more than seven working hours a day.
> 2. Sundays and two half-days off duty each week, to be spent as much as possible out of doors.
> 3. An annual holiday of one month, or two separate fortnights.[428]

The Committee's recommendations specific to radium therapy included using forceps and similar instruments for manipulating radium and radon sources, carrying radium in long handled lead-lined boxes, working as quickly as possible, storing radium in lead-shielded enclosures, and when handling radon, guarding against the escape of radon and ventilating the room with an exhaust fan.[429]

In November 1921, George Pfahler, a prominent Philadelphia radiologist and radium therapist, proposed to the Philadelphia Roentgen Society that it conduct a study of the blood of radiologists. The Society agreed and asked Pfahler to carry it out. He enlarged the proposal to include all of the x-ray and radium workers in America. A survey form was developed and over 1,000 were distributed; there were 338 responses. As part of the survey, a dental film marked with a lead number was included with instructions that it be carried for two weeks by the physician or worker and returned to Pfahler. The results were published in October 1922.[430] Of the results, Pfahler wrote, "Perhaps the most valuable contribution is that made by the medical director of one of our leading radium producing companies" who asked his name be withheld. Pfahler quoted extensively from his statement and it is clear it came from Dr. William Cameron. He stated that since the start of the company, there had been no deaths among its workers; but five workers, who constantly handled radium tubes and needles:

> …are suffering from radium effects on the thumb, index and middle fingers of both hands, *produced in the very early history of the laboratory* [emphasis added]. Since the establishment of regulations that radium must be handled with instruments, this local condition has not progressed in any one of the cases. The general health of the workers is, I believe, above the average.

Cameron provided employment data and blood profiles for the five workers and it is likely that the five are Charles H. Viol, Glenn D. Kammer, Arthur L. Miller, Henry T. Koenig, and Paul F. Hague. Cameron also noted a special case:

> [O]ne of the officers, not directly exposed to radium in the laboratories, has received during the past eight years, 90-130 mgm. [milligram] hours of gamma ray exposure to a pathological lesion. Treatment consists in the use of from 30 to 200 mgm. of radium used either directly on or buried in the growth. This officer is at the present time in good health.

The officer is obviously James Gray and Cameron's description is consistent with Gray's Congressional testimony in 1914 (chapter 6).

Pfahler's conclusions covered x-ray and radium workers, but the following were pertinent to radium workers:

> The skin changes found in the earlier workers are not increasing, and are being avoided entirely by the younger ones, because of the increased knowledge, and increased protection… Complete protection can undoubtedly be obtained. It requires not only the means, but the continual caution on the part of the individual… Increased protection is needed by those who are working with gamma rays… Shortening the hours of work, and increasing the amount of fresh air and recreation will probably remove symptoms, and prevent future trouble.

In April 1924, *Radium* reprinted an illustrated article by R. C. Williams, Assistant Surgeon, Office of Industrial Hygiene and Sanitation of the U. S. Public Health Service, on the physical condition of employees of the National Bureau of Standards engaged in the Bureau's radium program.[431] Nearly of all the radium sold by firms in the U.S. passed through the Bureau for calibration (figures 9.6-9.9). A distinguishing feature of this study was the experimental wearing of dental films by the workers to positively confirm exposure to radiation. A penny was glued to one side of each film and the films were worn on the forehead, neck, chest, and both inguinal regions. To calibrate the films, several similar films were exposed to known quantities of radium at different distances and lengths of time. The highest film exposures were to those worn on the forehead although it was acknowledged exposures to the hands and forearms would have been greater. The experiment showed that all the Bureau's employees in the radium program were exposed to radiation. Accordingly, all were given complete physical evaluations. Briefly, the study found two employees showed evidence of radiation effects on their fingers and hands, blood changes were documented, and it found that nearly all of the employees had low blood pressure.

In 1925 *Radium* ceased publication. Its articles had been mainly devoted to the medical application of radium. While its editors, Viol and Cameron, did not neglect radium safety, articles on the subject were few. Viol's candid account in 1916 of SCC's early painful experiences in handling radium was a lesson in self-discovery of the hazards of chronic exposure to radium because of lack of foreknowledge about the risk. Kammer's 1914 warning to Viol to have his assistant "weigh some of the tubes as you will expose yourself too much" was consistent with the recommendation of the German scientists in 1914 to provide workers with "[s]hort working hours and frequent vacations or change of occupation" and Ordway's 1916 recommendation to rotate staff handling radium sources. Viol's modified forceps helped to reduce exposures of fingers when tubing or otherwise handling tubes and needles and their use was consistent with the German scientists' recommendation in 1914 to use "long pincers." Shielding, recommended by virtually every experienced user of radium, was adopted. A SCC photo taken about 1921 of Kammer tubing radium show the presence of a "shadow shield" to reduce exposure of his upper torso and additional shielding appears to be in place behind his hands, probably to shield radiation from radium salts in storage on the table (figure 5.10). Less clear is whether SCC implemented changes to shorten employees' time spent working with radium and to rotate them to other duties.

Kammer was also warned about longer-term consequences — "watch out in four or five years from now" and Ordway warned of symptoms that "occurred very insidiously" that led to "more serious late effects such as atrophy, intractable ulceration and even cancer." Still, in 1916, Viol insisted that the radium burns to the thumbs and fingers of SCC workers were not of such severity "as to require special treatment" and Cameron, in his 1922 report to Pfahler, described the general health of SCC's workers as "above the average."[432] Time would tell; it would not prove kind.

* * *

To modern eyes, many of the photographs and movies taken of SCC operations are notable for the complete absence of measures to prevent and control the spread of radioactive contamination and exposures to radon, the gaseous radioactive decay product of radium. As well as being a health concern, the contamination interfered with laboratory measurements. Pierre Curie was frequently forced to delay performing laboratory procedures because of the contamination on his person and his clothes, and the Curies' laboratory had to be relocated because its original location had become so radioactive.[433]

In Vienna, a building for the Austrian Radium Institute was opened in October 1910. Locating the new building was an issue for the physicists because of concerns about noise, vibrations, and electrical interference from Vienna's streetcars. The location that was selected proved satisfactory in those regards, but a new issue emerged. As Stefan Meyer, the Institute Director admitted, "It was a new concern; we were setting up something untested, [prior] experiences of radioactive 'contamination,' mutual interference, and so on were for the most part absent."[434] Radioactive materials were initially stored in the cellar of the building along with a large electrical battery and a transformer, an arrangement that proved a mistake because the foot traffic to service the battery and transformer spread contamination throughout the building. Another mistake according to Victor Hess, the Institute's assistant director, was locating radiochemical laboratory and attendant spaces on the ground floor near the front entrance, a high traffic area.[435] This may have been just as responsible for facilitating spread of contamination.

In May 1913, *Radium* reported the new Radium Institute in Paris would consist of three buildings, one for the physical department headed by Marie Curie, and the other buildings for the chemical and physiological departments, noting that "separating the physical and chemical departments in different buildings is certainly a very happy one, as this scheme will prevent the physical measuring rooms with their delicate electrical apparatus from being 'infected' by induced radio-activity from chemical manipulations of radio-active substances..."[436]

SCC may have been aware of these concerns because it located the radium-refining laboratory on the top floor of the Vanadium Building, farthest from the building entrance. The location of SCC's assay laboratory has not been identified but a photograph of the room shows windows different from those in the Vanadium Building.[437] This suggests it was located in a building other than the Vanadium Building and thus well separated from the contamination in the laboratories.

* * *

At SCC there was no concern about internal exposure to radium. After all, SCC's Dr. Frederick Proescher had conducted clinical studies of the effects of internal administration of radium, found many patients benefited from the doses, and declared that intravenous injections of radium up to one milligram are "perfectly harmless."[438] Furthermore, the American Medical Association had deemed radium solutions for injection and drinking to be acceptable (chapter 5). This view of internal exposure to radium changed in 1925 when New Jersey pathologist, Dr. Harrison S. Martland, provided clear evidence that radium in the body was not "perfectly harmless." The evidence was in the bodies of radium dial painters — the radium and the diseases it caused.

Harrison S. Martland was born in Newark, New Jersey and received his medical degree in 1905 from Columbia University (figure 9.10).[439] After working as an assistant pathologist at the Russell Sage Institute of Pathology in New York City, he became pathologist at Newark City Hospital and the pathologist for the City of Newark. Martland also became assistant county physician for Essex County (New Jersey) and, in 1925, chief medical examiner. As such he had authority to investigate the deaths of workers who died in the county.

Martland was not the first to suspect a connection between the radium in luminous paints and the illnesses being seen in women employed to apply the paint to watch and instrument dials. That distinction belongs to Katherine Schaub, herself a radium dial painter.[440] In 1917 she and her cousin, Irene Rudolf, took jobs as dial painters at Radium Luminous Materials Corporation in Orange, New Jersey. Both were 15 years old. They worked on and off at the plant until 1920 or 1921. In the spring of 1922, Rudolf began having problems with teeth, gums and mouth. Initially, her dentist, Dr.Walter Barry and his partner, Dr. James Davidson, suspected phosphorus poisoning. They reported her case to the New Jersey Departments of Health and Labor which inspected the dial painting plant. No violations of industrial safety standards were found but a consulting chemist for the state Department of Labor, Martin Szamatolaski, concluded that radium was the cause of the dial painters' illnesses.[441] Rudolf died in July 1923. Her death certificate listed phosphorus poisoning as the cause. Schaub visited the state Departments of Health and Labor offices in Newark to dispute the certificate's statement. In November 1923 Schaub consulted the dentists about problems with her teeth. By this time Drs. Barry and Davidson had become aware of other dial painters with similar dental problems and had treated six of them. The symptoms were similar — loss of teeth, severe infections and necrosis of the jawbone accompanied by anemia. The former dial painters, their families, and the dentists concluded they were dealing with a new occupational disease and radium became increasingly suspect as the cause.

The first public reference connecting radium with the dial painters' disease was an address by Dr. Theodore Blum made to the American Dental Association in September 1924 in which he described a patient suffering osteomyelitis of the mandible and maxilla similar to phosphorus necrosis but which he thought was connected to the radioactive paint used in the manufacture of luminous dials for watches.[442] He suggested the condition be termed "radium jaw." Blum's address was referenced in a paper by statistician Frederick Hoffman who reported similar cases involving five women who had died and twelve other women, still living, who were employed as dial painters.[443] Hoffman believed the cases showed a link to a new occupational disease (although stopping short of naming radium as the cause) and called for the doing away with the practice of dial painters of drawing their paint brush bristles to a point with their lips.

On December 5, 1925, the *Journal of the American Medical Association* published a landmark paper on the subject by Dr. Harrison S. Martland, Philip Conlon, and Joseph P. Knef.[444] Martland and his co-authors minced no words:

> This report is published now as a warning that when long-lived radioactive substances are introduced into the body, either by way of the gastro-intestinal tract (as they were in these cases) or by way of intravenous injections for therapeutic effects (as is advocated for the treatment of such conditions as gout, arthritis, arteriosclerosis, leukemia and Hodgkin's disease), death may follow a long time after, from the effects of constant irradiation on the blood-forming centers. Minute particles of the radioactive substances are [transported and] deposited in the bones, spleen and liver in sufficient amounts to produce, for a

period of time, seemingly curative or stimulative reactions, to be followed later by exhaustion and destruction of the blood-producing centers.[445]

The authors' findings drew rebuttals from within the medical community, were vigorously attacked by the radium dial painting industry, and the controversy received extensive coverage by the news media.[446] What reaction there was at SCC is not known. *Radium* ceased publication in 1925 and so cannot be consulted for an answer. The findings came too late for the SCC employees who had worked in an environment devoid of contamination controls to prevent inhalation and ingestion of radium. The internal exposure to radium would have been in addition to the external irradiation of the workers' fingers, hands and bodies. For some of SCC's workers their exposures to radium would take a horrific toll.

* * *

Glenn Donald Kammer, a chemical engineer from the University of Pittsburgh, sustained severe burns of his fingers beginning the first year of his employment at SCC, 1913, losing the ends of both index fingers and thumbs.[447] During his employment by SCC he never took a vacation and his body became so radioactive that he could no longer use the instruments to measure radioactivity. In 1921, despite his injuries, Kammer prepared the gram of radium presented to Marie Curie (figure 9.11). By 1927, he became bedridden with anemia, the result of his work with radium, and underwent repeated blood transfusions to no avail.[448] On November 7, 1927, he died. He was 39 years old.

Just 10 days after Kammer's death, Paul F. Hague died. Hague, a 1908 Duquesne University graduate, worked for SCC from 1914 to 1923 in Colorado and Pittsburgh. In Pittsburgh he packed the crystalized radium salts and handled radium tubes with his bare hands.[449] Following development of skin cancer on a finger, it was amputated. He was hospitalized in August 1927 because of a deteriorating blood condition, developed pneumonia, and died August 17, 1927. He was 34 years old.[450]

On April 6, 1928 Charles H. Viol, the director of SCC's research and radium laboratories, died in New York City after spending two months in Memorial Hospital.[451] Early in his career at SCC his hands and forearm were severely burned by radium and these injuries were followed by the onset of cancer. Despite this, he continued to work with radium.[452] He was 42 years old.[453]

Henry Titus Koenig, a University of Pittsburgh chemist and classmate of Kammer, worked for SCC for two years mainly in the crystallization laboratory. He then became associated with Colorado radium production companies and later joined the Curie Laboratory in France.[454] On May 20, 1934, he passed away in Denver, Colorado at age 46 (figure 9.12).[455] Three months earlier, suffering from cancer of the hip, he was admitted to a Denver sanitarium for treatment but the cancer spread and led to his death. He was buried in Homewood Cemetery in Pittsburgh. In 1986 Argonne National Laboratory's Center for Human Radiobiology (CHR) obtained court approval to exhume his body as part of a government study examining the health effects of radium.[456]

The most dangerous SCC workplace in terms of exposure to radium was in Pittsburgh where radium was refined, tubed, and assayed. Kammer, Hague, Viol, and Koenig were engaged in this work. Another SCC employee involved in these tasks was Arthur L. Miller. Miller died March 3, 1963 in Pittsburgh.[457] He decided to leave SCC in 1929 after the deaths of Kammer, Hague, and Viol later explaining that otherwise "it wouldn't be long until I would be pushing up the daisies too."[458] Nonetheless, he occasionally agreed to requests to find lost sources, something he had done while at SCC.[459] Then, in 1939, he agreed to assist the New York City Memorial Hospital in relocating a huge quantity of radium, five grams, to a new building. The experience left him so physically and emotionally exhausted that he gave up his consulting business.[460] Although Miller survived his colleagues, he did not escape unscathed; part of a thumb that had been severely burned had to be removed. He was 70 years old at the time of his death; the cause was cancer.[461] Radium contaminated his house and it had to be remediated.[462]

There probably were other SCC workers who suffered long-term consequences and possibly died as a result of their employment but whose cases are not documented.[463] Physicians signing their death certificates would have had to be aware they had worked with radium and aware of a possible link between their final illnesses and that work.

* * *

What motivated Viol, Kammer, Hague, Koenig, Miller and others to continue working with radium even after evidence of injuries? In 1979 Elizabeth Rona, a Hungarian-American chemist who worked in radium laboratories in Europe from 1924 to 1940, recounted her observations of the early safety practices in the laboratories, the injuries and deaths suffered by the workers, and the attitudes to safety and research.[464] About the last, she commented:

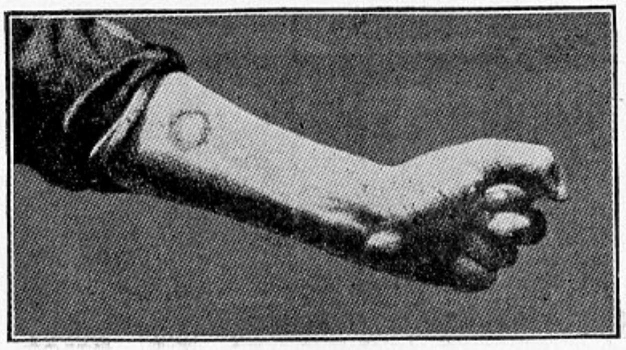
> In general, when institutions are devoted solely to basic research, the first consideration is that the work goes on as quickly and efficiently as possible; safety precautions would slow it down. The expensive and sometimes unique material should be secure under all conditions. The employed scientists and technicians should not be discouraged by fear of health problems. The head of institutions, who should have enforced safety rules, were probably honest in believing that no danger (at least immediate danger) existed because changes in the blood system, a sensitive organ for radiation, are slow.[465]

Rona's comments applied to SCC as well.

Alexander Silverman, head of the University of Pittsburgh Chemistry Department, mentored Kammer and Koenig and closely followed their careers and that of Viol. In 1945 he offered his perspective on their commitment to their work and its consequences:

> Kammer, Koenig, and Viol all died from the harmful effects of the powerful penetrating rays of radium. On the other hand, thousands of individuals have been cured by its proper application in the treatment of cancer. The pioneers suffered the consequences of inexperience in the handling of this substance which is both so deadly and so beneficial.[466]

Perhaps Glenn Kammer's widow, Marion Condon Kammer, spoke for many of SCC's scientists when she remarked her husband "had no conception of what radium might do, but he was the pure scientist and went on to see."[467]



9.1 A photograph of the radium burn on Pierre Curie’s arm. *JOL*

Valise Used by Glenn Donald Kammer for Transporting Four Grams, the First Shipment of American Radium to Europe, to England during World War I

9.2 The original caption says it all. Although the valise was packed with lead shielding to the point it could hardly be carried by Glenn D. Kammer, four grams was a huge quantity of radium to carry in it. *ACS2*

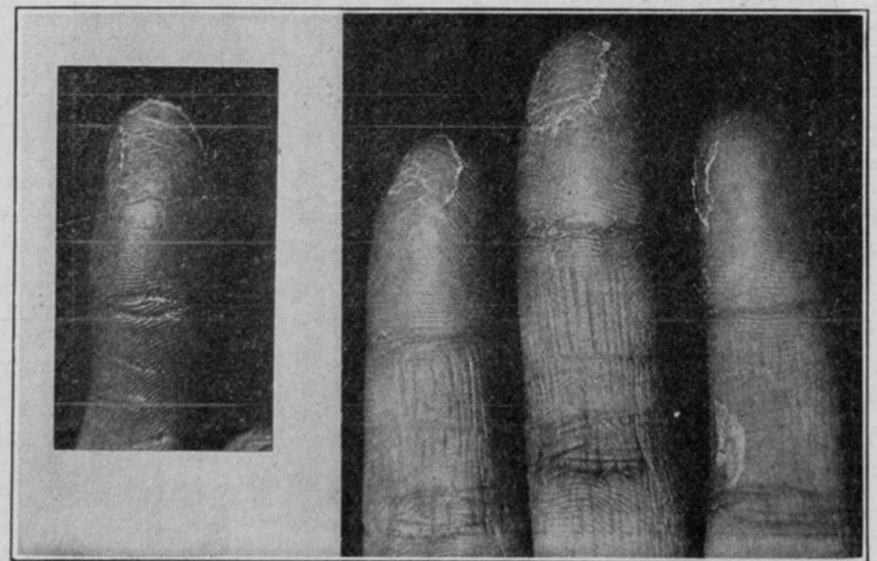
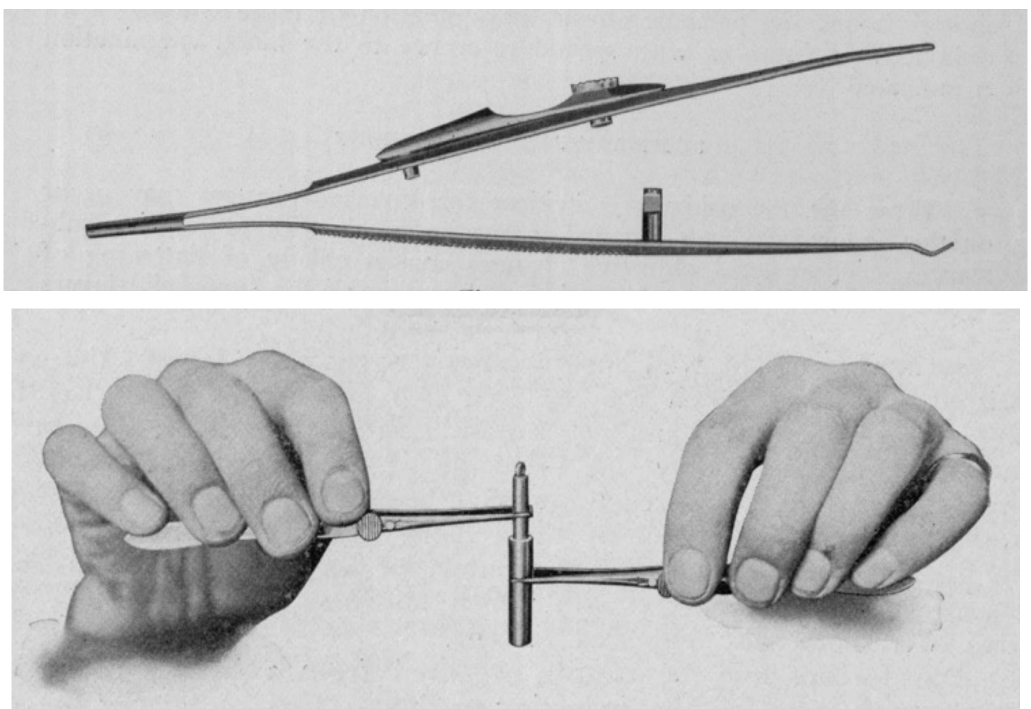
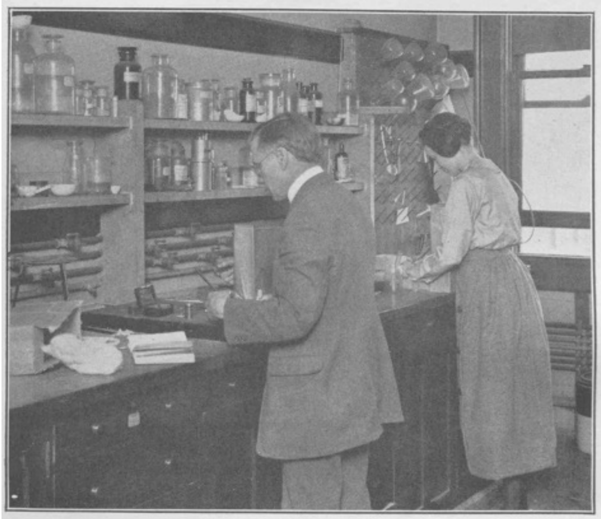


Fig. 6 (Case 3).—Photograph of thumb, index, middle and ring fingers of left hand showing the scaling of the thickened superficial layer of the skin on the radial side of the terminal phalanges and also a similar small area on the second phalanyx of the ring finger.

9.3 An example of radiation damage to a thumb and fingers from exposure to radium. *CPP*

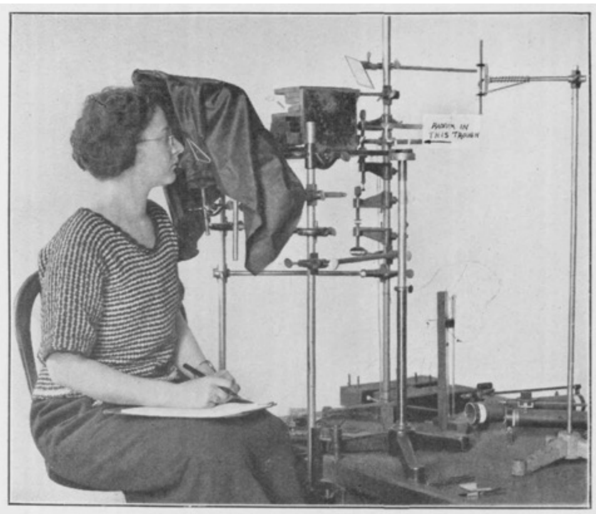


9.4, 9.5 Using tweezers when handling radium sources, instead of handling them directly with fingers and thumbs, greatly reduced the radiation dose to the hands. Viol modified tweezers to lock, making them easier to use. *CPP*



Unpacking and packing radium

At the radium safe. Representing (1) taking inventory, and (2) removal of radium to and from safe for storage, measurement, and packing.

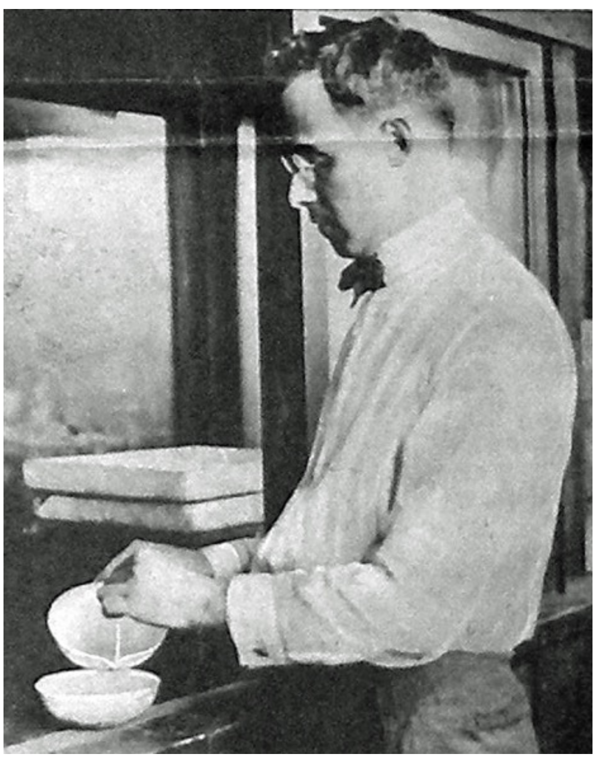


Measuring radium by means of the gamma ray electroscope—the standard method used for all but exceedingly weak preparations.

Making measurements of length, diameter, and weight of radium tubes, needles, and plaques for purposes of future identification.

9.6 – 9.9 U.S. National Bureau of Standards employees in the radium calibration facility. Clockwise, from top left, unpacking and packing radium sources, the radium safe, making physical measurements of the length, diameter and weight of radium tubes, and measuring radium using an electroscope. *CPP*

9.10 Right, Dr. Harrison S. Martland in 1917 at the seat of his Mercer Speedabout roadster after he was inducted in military service as a 1st Lieutenant. The right-hand drive was common to roadsters at the time. *RU*



9.11 Left, Glenn D. Kammer handling two grams of radium in solution, half of which is destined for Marie Curie. Note the absence of shielding and contamination controls. *HHC3* 9.12 Right, Henry T. Koenig, a University of Pittsburgh classmate of Glenn D. Kammer. *ACS1*

Chapter 10: Legacies

"Standard Chemical Company's value was reduced to $15,000."

By the time Marie Curie returned to France in June 1921, SCC had produced 75.5 grams of radium, a figure that included 1.5 grams produced in 1911 and 1912 during the research and development phase and 74 grams of commercial production through June 1921.[468] From July to mid-October another 6.5 grams was produced.[469] At that point, a national economic slump that had begun in 1920 had reduced demand for radium so much that SCC shut its mining and mill operations in Colorado.[470] The depression of 1920-1921 has been called the forgotten depression because it was overshadowed by the depression of the 1930s.[471] At its worst, unemployment rose from four to nearly twelve percent and the Gross National Product fell seventeen percent. Not only had the demand for radium diminished, so did demand for vanadium byproduct because of the depressed state of the steel industry.[472] In Colorado John Mullen took advantage of the shutdown to assign miners to search for additional reserves of ore to strengthen SCC's position when the recession ended.[473] The economy did rebound, but another development came into play — radium produced from a foreign supplier that cost much less then SCC's radium. This would have a lasting, devastating effect on SCC.

* * *

In 1906 in Belgium a new company, Union Minière du Haut Katanga (UMHK), was organized to exploit copper and other mineral resources found in the Katanga region of the Belgian Congo colony in Africa.[474] During World War I uranium ore deposits were discovered as well. While preliminary analyses of the ore disclosed it was exceptionally rich, 40-50% U_3O_8, mining had to be postponed because the company's resources were needed for copper production for the war effort in Europe.[475] A post-war economic downturn further delayed development. Finally, in late 1921, UMHK turned its attention to this resource and shipped twelve tons of the ore to a radium production plant that it was building in Oolen, near Antwerp.[476]

American radium chemists from the Radium Company of Colorado, the second largest American producer, assisted in the design of the plant. The Americans included Henry T. Koenig and probably Willy A. Schlesinger, both former SCC chemists.[477] While there, UHMK officials asked the Americans to partner with their company, an arrangement that would provide UHMK access to the American company's experience in production and marketing.[478] UMHK planned to sell radium for $70,000 per gram thanks to the exceptional rich U_3O_8 content of the African ore and the lower costs to mine it.[479] That was about what it cost American companies to produce radium, leaving the Americans no profit margin if they sold radium at the same price. Under these circumstances, the offer from UMHK was the best arrangement available for the American side. SCC learned of the UHMK developments and, in 1922, SCC officials led by James Gray met with UHMK representatives in Belgium and negotiated a five-year contract with UHMK, effective 1923, to sell their radium in the U.S.[480] Under its terms, SCC was to purchase nine grams of radium annually from UMHK at $50,000 per gram and SCC was to cease its own production of radium from carnotite.[481] The agreement ended any prospect for the Canonsburg plant to resume production of radium. In 1927, following a damaging fire the previous year, the plant was dismantled.[482]

Although SCC was no longer permitted by the UMHK agreement to produce radium, the carnotite ore contained another valuable metal — vanadium. There was no operational factor preventing SCC from extracting only the vanadium from carnotite but there was a legal one that was contained in another agreement. When J. Leonard Replogle's syndicate purchased the American Vanadium Company in 1916, it agreed the SCC could continue marketing vanadium only if it was a byproduct of the Canonsburg plant to produce radium.[483] Since changing the primary purpose of the plant to produce vanadium was prohibited by this agreement the Canonsburg plant never reopened.

On May 1, 1925, James Gray died.[484] Albert R. Raymer was elected by the SCC Board of Directors to succeed Gray.[485] Raymer's connection to the Flannerys dated to 1913 when he was a SCC Board member and became vice-president in 1917. Other officers were Joseph Flannery's brother-in-law, vice-president Thomas J Gearing, treasurer Harry A. Neeb, and secretary Charles H. Viol. Other board members were Joseph Flannery's son-in-law, Joseph A. Kelly, W. S. VanDyke, C.B. Aylesworth, J.M. Schoonmaker, and H. C. Sherrard, all of Pittsburgh.[486]

In 1926, Gearing and Kelly met with UMHK officials in Brussels, Belgium seeking renewal of the contract with UMHK. The Belgian firm informed them that it planned to enter the American market itself. Gearing and Kelly were offered positions with UMHK and 25 grams of unsold radium would be repurchased by UMHK in return for the goodwill and sales organization of SCC.[487] They agreed and Radium Chemical Company (RCC), once SCC's marketing subsidiary, became the U.S. sales agent for Belgian radium in the U.S.

Under this agreement, SCC no longer had production responsibilities and it began disposing its properties beginning with the sale in 1928 of the Joe Jr. mill and its mining claims in Paradox Valley to the United States Vanadium Company (USV), a subsidiary of the Union Carbide and Carbon Corporation (UCC).[488] The following year, the Canonsburg property was sold to the Vitro Manufacturing Company. [489]

The sales left little in SCC tangible assets. The Board of Directors reduced the par value of SCC's 15,000 shares from $100 to $10 in 1928 and again, in 1930, to $1. Once capitalized at $1,500,000, Standard Chemical Company's value was reduced to $15,000. Finally, in November 1933, twelve SCC stockholders controlling 11,278 shares, voted to dissolve the company.[490] Gearing held the largest block, 9,928 shares. The smallest shareholder was Joseph Flannery, Jr., Flannery's eldest son. He held three shares. He, too, voted approval.

The RCC remained in the Vanadium Building in Pittsburgh. UMHK shipped its radium to RCC in the form of a refined radium-barium bromide salt thus eliminating the need for the fractional crystallization laboratory that had been used by SCC.[491] The only chemistry that was performed was converting the bromide to sulfate salt since most medical radium users preferred that form. The remaining operations to manufacture medical sources were continued.

Gearing and Kelly began taking steps to relocate the operations to New York City, a move that may have been suggested by UMHK. In 1933 a new company, Radium Chemical

Company, Incorporated (RCC Inc.) was organized in New York, the addition of "Incorporated" distinguishing the name of the new entity from RCC. RCC Inc. provided the corporate framework for operation in New York City and replaced RCC as UMHK's sales agent. The major stockholders in RCC Inc. were Thomas J. Gearing, president, and Joseph A. Kelly, secretary, each holding an equal number of shares.[492] A 1936 consolidation of RCC Inc. with three other companies previously created by Gearing and Kelly completed the transformation.[493] In 1937, RCC Inc. closed its operations in the Vanadium Building, which had been renamed the Flannery Building, and relocated to New York City.[494]

The deaths of the Flannery brothers, the sale of SCC's properties and its liquidation, and the move of RCC Inc. to New York City should have been the closing chapters of the story of the Flannery brothers' pioneering venture into radium production. But left was an unexpected, unwanted legacy — radioactive residues of the milling of carnotite ore in Paradox Valley, radioactive tailings from the extraction of radium from the ore in Canonsburg, and radioactive contamination of the Vanadium Building in Pittsburgh from the refining of the radium and manufacture of radium products. Additionally, in Paradox Valley and Canonsburg, the wastes from SCC operations later became comingled with waste from the production of uranium for use in atomic bombs, work that was carried out during World War II for the Manhattan Engineering District (MED) and then for the U.S. Atomic Energy Commission (AEC).

The environmental radioactive contamination in Paradox Valley and Canonsburg was extensive and radiation from it exceeded permissible levels. In Canonsburg, the Nuclear Regulatory Commission at times seemed unaware of the problems, and at other times took actions that conflicted with other federal and state agencies' advice. In Pittsburgh, SCC's use of the Vanadium Building was forgotten. Once the residual contamination was discovered it was found the radiation levels exceeded permissible levels. Initial attempts to deal with the contamination failed.

Remediating these sites proved controversial, took decades to accomplish, cost millions of dollars, and required governmental intervention. Underlying the controversy were public concerns about exposure to radiation from the contamination, disagreements over disposal of residual radioactive wastes, and confusion about the actions taken by state and federal agencies.

* * *

Paradox Valley

When SCC shut the Joe Jr. mill in Paradox Valley in October 1921 it employed 275 workers in the valley.[495] Up to that point, SCC had spent $4,750,000 and mined 48,000 tons ore carnotite ore for radium production, ninety-two percent of all U.S. mining of radium ore.[496] In 1922, as the economy recovered and demand for vanadium resumed, the mill operated intermittently to concentrate carnotite for its vanadium content, an operation that apparently did not conflict with the AVC agreement. At one point, the mill operated 24 hours a day employing 150 men working three shifts, but this was cut back in October 1922 when 100 workers were laid off.[497] When demand and prices for vanadium increased in 1923 SCC assigned crews to scour ore dumps to pick out high value vanadium ore and announced it would overhaul the mill in expectation of resuming of operations.[498] But the next year SCC shifted its attention from vanadium ore to developing oil wells in Paradox Valley.[499]

SCC sold the Joe Jr. property to the U.S. Vanadium Company (USV) in 1928. At the time of the sale, USV was based in Rifle, Colorado where it operated a plant extracting vanadium from ore. USV moved its operations to the Joe Jr. where it constructed a new plant and a new town for an estimated 250 employees and their families. [500] The town was named "Uravan," a name derived by combining the first syllables of uranium and vanadium. Uravan was in all respects a company town — USV built its homes, churches, an elementary school, medical clinic, community hall, general and drug stores, barber shop, and the supporting infrastructure that included power plants, a water system, and septic tanks for the homes. Most workers spent six days each week at the plant. Many of the town's residents came from the nearby communities of Nucla, Naturita, Norwood, and Coke Oven. Families spent their leisure time together playing cards, hosting parties, and during the summer in sports such as baseball. Food, coal, and other goods, much of which originated in the nearby communities, was trucked in. Once again, mining and processing of carnotite ore had become an important economic engine for western Montrose Country.

Initially, uranium was a waste product except for limited quantities sold for use as coloring agent for ceramics and glass. By 1937, as war clouds gathered in Europe, attention again turned to uranium as a hardening agent for steel and USV added a uranium extraction circuit to its plant. In 1942 the MED was established with the objective of nuclear weapons production. Uranium, once an orphan metal for which Joseph Flannery despaired of finding uses, became a metal having strategic importance. MED contracted with USV to reprocess tailings from other mills in Colorado and Utah to recover the uranium. To process these tailings, two more plants were built. Uravan's population grew as more workers were employed to staff the mills and as military and civilian government personnel were assigned to the area. To accommodate them, the government built new housing that included single-family homes, apartment houses, and a trailer court. The SCC boarding house and newly-built Quonset huts were used to house unmarried workers. To maximize uranium production, the mills operated continuously day and night, causing a labor shortage. USV was given permission to hire boys as young as age sixteen and women age eighteen years. To protect the mills, the army fenced the area and posted police at the entrances to the town. Although mill workers knew they producing uranium for the government, they did not know for what purpose. That was revealed by news of the atomic bombings of Hiroshima and Nagasaki.

The government's demand for uranium ended, at least temporarily, with the war's end. The mills were dismantled and most of Uravan was mothballed.[501] In 1946, Congress established the Atomic Energy Commission (AEC) to provide civilian control of the production and utilization of nuclear materials. Once again, the government contracted for the production of uranium, and Uravan was reborn as a boomtown, its population peaking at about 1,000 (figure 10.1).[502] This boom ended in 1970 when the government ceased its uranium buying program and the price for uranium declined. The prices declined further after the Three Mile Island nuclear power plant accident in 1979 and the subsequent slowdown of orders for and construction of nuclear power plants. Another factor was growing concern about the environmental impact of uranium mining and milling, especially the radioactive mill tailings.[503] In 1984, Uravan's mill was closed for the final time and most of Uravan was vacated.

To address environmental concerns about uranium mill tailings Congress enacted the Uranium Mill Tailings Radiation Control Act (UMTRCA) in 1978. The Act placed mill tailings under the jurisdiction of the U. S. Nuclear Regulatory Commission (NRC) which had succeeded the AEC in 1974 for regulation of nuclear materials. Title I of the Act covered twenty-two sites where mills had closed ("legacy sites") and provided federal funding to remediate the sites. Title II covered mills still in operation and required operators to manage the tailings to minimize environmental impacts.

When UMTRCA was enacted, the Uravan mill was operational so it became a Title II site. In 1983, the state of Colorado filed a Natural Resources Damages (NRD) claim against UCC and its subsidiary, Umetco Minerals Corporations (Umetco), under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), also known as the Superfund Act. In 1984, when the mill was closed, the site was proposed to the U. S. Environmental Protection Agency (EPA) National Priorities List (NPL). The state was designated the lead agency for negotiations with UCC and Umetco to develop a remediation plan. In 1987, the U.S. District Court approved the plan.[504]

Cleanup of the site included capping nearly 10 million cubic yards of radioactive tailings, disposing 530,000 cubic yards of dried residual salts from liquid processing waste, securing 12 million yards of tailings waste along the river, eliminating process ponds, pumping and treating contaminated groundwater, dismantling mills and related buildings, and demolishing the town at a cost of $127 million.[505] Maintenance and long-term surveillance of the site is the responsibility of the U.S. Department of Energy (DOE).

Still remaining on the site were the original SCC boarding house and the Uravan community center, also known as the recreation hall (figure 10.2). In 1994, a survey of former residents of Uravan showed overwhelming support for preservation of the buildings and the local historical society, the Rimrocker Historical Society of Western Montrose County, secured the listing of the Uravan site in the Register of Historic Properties for the State of Colorado.[506] In 2005, the EPA deleted 10 acres from the NPL that included the two historic structures.[507] Unfortunately, the buildings were determined not to be structurally salvageable and in 2007 were demolished.[508] In 2012, control of the 10 acres passed to the historical society which uses it for its annual reunions of former Uravan workers and their families.[509]

The Uravan site also contains waste from a mill that had been built near Naturita. The mill was closed when UMTRCA was enacted so it was designated as one of the twenty-two Title 1 sites. To remediate it, 971,792 dry tons of contaminated soil and building debris were removed to an engineered disposal cell near the former Uravan town.[510] The 27-acre tract of land containing the disposal cell is owned by the U.S. government, is enclosed by a perimeter fence posted with warning and no-trespassing signs, and contains two granite site markers identifying area as the Naturita disposal site. The cell contains an estimated 79 curies (grams) of radium. Title I sites are licensed by the NRC which requires a long-term surveillance program that includes periodic inspections, maintenance and repairs, environmental monitoring, and institutional controls to limit access. DOE periodically conducts inspections of the sites.[511]

* * *

Canonsburg[512]

About 1930, the Vitro Manufacturing Company acquired the Canonsburg site. The company had been organized in Pennsylvania in 1909. In 1950, a subsidiary, Vitro Chemical Company, was formed and in 1953 the companies came under an umbrella organization, Vitro Corporation of America. Vitro Rare Metals Company was another member of the Vitro family. For simplicity, "Vitro" is used as the common name.[513] Vitro specialized in production of coloring mediums for enamels, ceramic, glass, and cement using chemicals such as chromium oxide, cadmium sulfide and uranium compounds.[514] In 1934, Howard Balsey, a Colorado ore broker, signed a contract with Vitro to supply uranium ore.[515]

From 1942 to 1957, under contracts with MED and later with the AEC, Vitro recovered uranium and other metals from ores and by reprocessing waste and scrap materials from other AEC contractors (figure 10.3).[516] In 1956 and 1957, Vitro, with the AEC's approval, removed 11,600 tons of waste material from Canonsburg to a Pennsylvania Railroad disposal site near Blairsville Pennsylvania (subsequently named the Burrell site for its location in Lower Burrell Township in Indiana County). Neither the AEC nor Vitro informed the state of this transfer. In 1958 Vitro, faced with continuing operating losses, shut down the plant, and in 1960, it laid-off all its employees and vacated the property.[517] The 18-acre site was sold in 1962 to a local company, the Canon Development Company. As part of the sales agreement, Vitro promised to clean up the site, but little was done.

Concern about the lack of progress in cleaning up the site led an investor in the development company to write Pennsylvania Governor William Scranton for assistance in April 1963. The Governor's representative in Washington, former U.S. Representative James Van Zandt, arranged a meeting with the AEC officials about cleaning up the site. About this time, the Pennsylvania Department of Health learned of this. In May 1963, the AEC cited Vitro for a number of safety violations. Surprisingly, the AEC did not know that Vitro had closed the plant, laid-off its employees, and sold the property.

In response to complaints about having not cleaned up the Canonsburg site, Vitro insisted it was trying to comply with the AEC regulations but was hampered by difficulties in getting permission from the new property owners to work on the property, and by having to deal with two government agencies, AEC and the state Health Department. In May 1963, John Villforth, a U.S. Public Health Service officer, visited the site and wrote a report highly critical of the AEC's oversight. Meanwhile, Thomas Gerusky, head of the Pennsylvania Health Department's radiation control program, learned that Vitro was lobbying in Harrisburg and Washington DC for approval to dispose the remaining contaminated waste material at the Canonsburg site rather than dispose them elsewhere.

There were several common denominators as the controversy intensified: cleanup of the site was needed, removal of the contaminated materials from the plant site was sought, and speedy resolution was desired. In 1964, when the Canon Development Company raised the possibility of a lawsuit to force Vitro to act, Vitro agreed to decontaminate the site buildings at its own expense, provided they could dispose of the waste material in a sludge lagoon had been previously used to dispose of plant waste on land it owned on the other side of a road that crossed the property. The Canon Development Company agreed to this proposal. The state Department of Health's Director of Occupational Health, Dr. Jan Lieben, objected because such disposal would violate the AEC's regulations requiring such waste be disposed on government-owned land. In January 1965, the AEC informed Lieben that it would approve the burial under a special exemption provision of its regulations. Lieben again objected, pointing out that the site would require periodic monitoring, and that if problems developed, the local or state governments would find themselves owners of the land. The waste material was buried in the lagoon in 1965 and covered by "red-dog," a paving material using burnt coal refuse as its granular base material.[518] Later, it was filled in, seeded, and used as a baseball field.[519]

AEC officials argued that its legal basis for making its decision was limited because it had jurisdiction only over the uranium in the waste, but no jurisdiction over radium that was intermixed with it. Radium had been excluded from the 1946 Atomic Energy Act because it had no role in atomic energy.[520] Lieben's prediction came true — problems developed at the Canonsburg site and because of them, the site came under state ownership. Radioactive material in the waste that the AEC did not regulate, radium, caused the problems.

After the 1965 burial was completed, AEC officials conceded that radiation levels in parts of the site were above its regulatory limits. Robert Gallaghar, a certified health physicist and consultant, visited the site at the request of a representative of the Canon Development Company to make radiation measurements. On top of a slag pile at the closed Vitro plant, Gallaghar was startled at finding radiation levels over 20 times the permissible level for the area. The "slag" consisted of uranium ore tailings from Canada that Vitro had contracted to reprocess to extract the uranium. Vitro found that it was not economically feasible and abandoned the project. When the company shuttered the plant in 1960 it simply left the pile there. Gallaghar informed his client the plant was unfit for use, the pile should be removed, and that radon, the gaseous radioactive decay product of radium, was a possible risk as well. Gallaghar was further surprised to learn that not only had the AEC approved the burial of the waste at the lagoon site instead of government-owned land but also the AEC had then terminated Vitro's license after the 1965 burial.

In August 1967, Canon Development Company sold the property to Vaughn Crile and John Labosky, two business owners from nearby Washington and Houston, Pennsylvania, who renamed it the "Canonsburg Industrial Park." Crile's and Labosky's companies were expanding and moved them to the industrial park. Their purchase of the property was predicated on the AEC's allowing Vitro to bury its wastes in the lagoon and terminating Vitro's license, actions that implied the property was safe to use. Other businesses followed them, and eventually about 200 workers were employed at the park.

In the 1970s, federal and state inspectors visited the site to conduct radiation surveys. They found significant soil contamination and elevated levels of radon in the park's buildings. Ground and aerial radiation surveys in Canonsburg disclosed "hot-spots" off-site in nearby properties. Additional cleanup was clearly needed, but less clear was under what authority could cleanup be ordered, and who would pay the costs? Clarity came with the passage of UMTRCA in 1978 which identified 22 legacy sites eligible for cleanup paid by the federal government; of these, 21 were in western states. The 22nd was the Canonsburg site; U.S. Representative Austin J. Murphy, from Monongahela, a member of the House Interior Committee, saw to it that it was included in the Act.[521] The Canonsburg site was chosen as the first site to be remediated. As a first step, it had to be vacated (figure 10.4).

Of the residual radioactive material on the site and its environs, some originated from SCC's operations, some came from Vitro's operations, and most of it was comingled. Strictly speaking, the federal government was responsible for Vitro's waste only since it came from processing ore and residues for the MED and the AEC. Separating the wastes was not practicable. Recognizing this, the federal government, while declining to bear the full cost of remediation, agreed to pay 90 percent of the cost, leaving the rest to be paid by the state. Gerusky, director of the state radiation control program, commented that 90 percent was probably more than the federal fair share of the problem and emphasized the federal offer meant there would finally be enough funds available to take care of the problem. For the owners of the park, this was mixed news. No longer was there uncertainty about the need for remediation, but UMTRCA required the site to be vacated and acquired by the government. After lengthy negotiations over what constituted a fair appraisal of the property's value, the state took possession under eminent domain proceedings in February 1982.[522]

In addition to contamination of the plant site, there was the matter of off-site "hot-spots." After the Vitro plant shut down its former employees salvaged equipment and materials from it. In one case staves (wooden side planks) from the processing equipment tanks were used to make a workbench, and in another case, were used as roofing material.[523] Other examples included salvaging bricks to make a garden walk, using tailings as fill for two playgrounds, and moving a tank to a garden to serve as a rain barrel.[524] All of these materials were radioactively contaminated. Other hot-spots were the result of SCC's practice of allowing its tailings to be used as road fill and the local use of radium fertilizer (chapter 7). In all, radioactively contaminated material had to be removed from 163 off-site locations and brought to the Canonsburg site.[525] There it was consolidated with rubble from dismantling the plant and other on-site radioactive materials from the site and placed into an engineered disposal cell. The cell, closed in 1985, contains approximately 226,000 dry tons (about 161,000 cubic yards) of contaminated material with a total activity of 100 curies (grams) of radium (figure 10.5).[526] The site is now surrounded by a fence posted with warning and no-trespassing signs (figure 10.6). Two granite monuments inside the fence inform visitors of the purpose of the site (figure 10.7).

Since Chartiers Creek borders the site, erosion controls were installed on its banks. As in the case of other Title I sites, the DOE periodically inspects it.

The Burrell site was remediated in a similar manner as part of the Canonsburg project. The engineered disposal cell was closed in 1987. It contained about 86,000 dry tons (73,000 cubic yards) of contaminated material with a total activity of about 4 curies (grams) of radium.[527]

The concerns about the safety of the site and the AEC's oversight that were raised by public health and radiation safety professionals such as Lieben, Villforth, Gallaghar, and Gerusky proved to be on the mark and remarkably prescient. They were not the only ones concerned.

As controversy grew, residents of Canonsburg and nearby communities became increasingly worried about their own safety which became the subject of a documentary video. Beginning in 1979, Gerald Saldo and Joan Engel, independent video producers, followed residents of Canonsburg as they met with state and federal officials and University of Pittsburgh scientists seeking answers to their questions about the dangers. Ms. Engel had a personal interest because the town next to the plant, Strabane, was her hometown, she and her family members lived a few blocks from the plant, and her sister-in-law had helped organize a citizens' action group, United Citizens Awareness to Radiation Exposure, UCARE. The video was entitled, "No Immediate Danger." It came from AEC's statement that while remediation of the site was necessary, there was no immediate danger, a not entirely reassuring comment.[528] The ties of Saldo and Engel to the community coupled with their lack of formal press credentials served them well. Community members grew comfortable speaking with them while being videotaped and government officials considered them part of UCARE and not members of the press. New York City's Museum of Modern Art showed the video in the spring of 1983 and it received the Silver Hugo Award for Video Documentary at the 18th Chicago International Film Festival.[529]

* * *

Pittsburgh

After the RCC Inc. vacated the Flannery Building in 1937 its history as a center for radium research and production faded from memory. In 1949, the University of Pittsburgh established a Graduate School of Public Health and appointed Dr. Adolph G. Kammer Professor and Head of the Department of Occupational Health.[530] On a rainy afternoon in 1957, his wife leafed through the telephone directory to find others with the same surname and found a listing for Mrs. Glenn Kammer right under their name.[531] She called and learned she was the widow of Glenn Kammer, a radium chemist who had died of radium poisoning after working for the SCC in the Vanadium Building. She informed her husband who then wondered if the building was contaminated. The Vanadium Building, renamed the Flannery Building, is within easy walking distance of the Graduate School of Public Health, so Prof. Kammer asked the university's radiation safety officer, Herman Cember, to visit it. When Cember approached the building carrying a radiation detector he "got a fair reading outside the building." He did not enter the building but returned to the university campus and reported his finding to Dr. Kammer. Dr. Kammer informed his occupational health counterpart at the state Department of Health, Dr. Jan

Lieben. Lieben felt the story "sounded a little fantastic" and asked Al Stang, the Department's Industrial Hygienist in Pittsburgh, to check the building. In December 1957, Stang reported that he found heavy radioactive contamination all over the 5th floor. The building, he learned, was owned by a religious fraternal organization.

The Department ordered the fifth floor evacuated until it was decontaminated. In this era, acceptable practices for decontamination utilized simple surface cleaning techniques to reduce external exposure levels to the limits prescribed by regulations.[532] In cases where residual contamination still remained it was fixed in place using paint manufactured for that purpose and then covered by new wallboard or flooring. When necessary, lead sheeting or high-density concrete was installed to further reduce external radiation levels. Absent from consideration were the consequences of future activities such as remodeling, building maintenance, repairs, and demolition that might disturb the remaining contamination. Although exposure to radon was recognized as a potential occupational hazard in radium workplaces, it had not yet become recognized as a potential health hazard elsewhere. Detailed regulatory criteria for remediation and regulatory guidance for determining compliance with the criteria did not exist. There was no formal licensing program for radium to provide a regulatory mechanism to review and approve decommissioning plans.

The Department sought to keep the case "under wraps to avoid panic" but it came to light on May 1, 1960 in the *Pittsburgh Post-Gazette & Sun-Telegraph.*[533] In 1960, after completion of the decontamination work, the Department resurveyed it and found it "O.K." (Lieben's words) and the fifth floor was leased to the university to house the Graduate School of Public Health's computer.

But subsequent surveys of the building revealed radium contamination still present on all levels of the building, including the roof and basement and that exposure of persons working in building to radon was an issue.[534] Decontamination activities resumed in the 1970s focusing on specific areas within the building, namely the fourth and fifth floors and the basement, and included replacing the original flooring materials with concrete. In January 1984, the state radiation control program issued a letter stating the building met radiation protection guidance for public use.[‡] The letter did *not* declare it free of radioactive contamination but did not explicitly state this, an omission that led to a misunderstanding of the building's condition.

The building was now owned by a savings bank. Based upon the state's 1984 letter the bank sold the building with the bill of sale stating it was "free of contamination." After the sale, the buyer, having concerns about the possibility of residual contamination, arranged for an independent radiation survey of the building. It disclosed both residual contamination and elevated levels of radon. A second independent survey was performed in which ten thousand radiation measurements were made — the most comprehensive survey of the building yet made. The survey report, issued in 1994, found the contamination was widespread. In 1998, the bank

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[‡] By this time the state radiation control program moved from the Department of Health to the Department of Environmental Protection.

and the buyer agreed to an out-of-court settlement that voided the sale leaving the bank in possession of property that was potentially valuable if it could be decontaminated; otherwise it represented a significant liability.

In September 1999, the state issued a radioactive material license to the bank restricting access to the building, setting remediation criteria, and establishing procedures to remove and dispose the contaminated materials. The contractor in charge of the remediation was confronted with a host of challenges, such as having to carry out the project in a highly populated urban setting near a university campus, dealing with a number of antique architectural and construction techniques and materials not normally encountered when remediating conventional nuclear-industry structures. Other issues were the modifications that had been made to the building after it was built but not documented, and locating contaminated pipes, drains, and mechanical systems hidden in columns and walls. Yet another complicating factor was the presence of asbestos.

After completing the decontamination work, the contractor made 44,000 individual radiation measurements to document the final radiological conditions of the building. Another 15,500 measurements were made at the request of the state. Computer programs then processed the data to estimate radiation exposures of persons in the building under a variety of scenarios, such as residents if the building was used as a dormitory, or workers if the building was used for offices. Other scenarios evaluated were radiation exposures to maintenance staff and to workers involved in future remodeling of the building. In the event the building was demolished, radiation exposures were calculated for demolition workers and for persons using the land afterwards for industrial or residential development.

After evaluating the decontamination work and radiation exposure assessments, the state terminated the license in September 2003 and released the building for public use.[535] (figure 10.8). The work was completed seventy-four years after RCC Inc. vacated the building and forty-five years after Cember's discovering it was contaminated. Unofficially the cost was $8 million.[536] Unlike the Uravan and Canonsburg sites, the Vanadium Building had no tie-in with the MED or AEC, and therefore no federal funds were available. The building owner, Parkvale Savings Bank, paid the cost and the building now bears its name. Another notable difference is that unlike the Uravan and Canonsburg sites where radiation hazards require restrictions on public access, there are no such restrictions for the Parkvale Building. The bank sold it to a real estate company that leased it to University of Pittsburgh Medical Center.[537] In November 2005, the university moved its English Language Institute of Pittsburgh to the building's first floor and mezzanine.[538] A surviving remnant of the SCC era is the double door bank vault once used to store radium. The Institute converted it to a student lounge, a novel repurposing of the historical space (figures 10.9 & 10.10). In 2018, the University of Pittsburgh acquired the building.[539]

Horace Rudy's stained-glass vanadium window was removed from the building, probably when the building was emptied for remediation. Fortunately, the Pittsburgh History and Landmarks Foundation (PHLF) saved it and donated it to the Historical Society of Western Pennsylvania at the Senator John Heinz History Center.[540] Kirk Weaver Glass Restoration, now

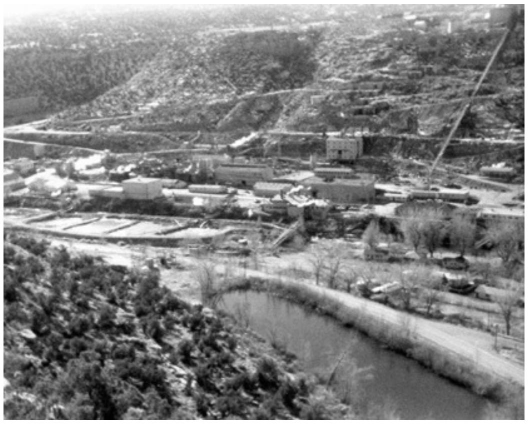
Pittsburgh Stained Glass Studios, cleaned and repaired the window using a grant from the Hillman Foundation.[541] Once again it can be seen — by visiting the Special Collections Gallery in the Sigo Falk Collections Center of the Senator John Heinz History Center.

* * *

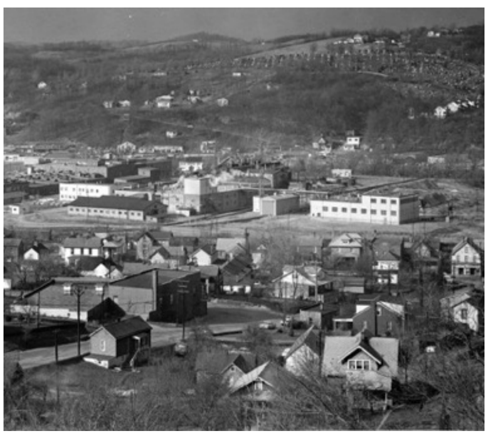
The Legacies of James J. and Joseph M. Flannery

When Joseph Flannery began his inquiries in 1909 about radium to treat his sister's cancer, there were only three American physicians seriously engaged in radium therapy; Francis H. Williams in Boston, Howard Kelly in Baltimore, and Robert Abbe in New York. That changed thanks to the Flannery brothers' decision to produce radium, and SCC's innovative combining of medical research and marketing to create a domestic demand for medical radium. In 1916, with the active encouragement of the SCC, 22 charter members organized the American Radium Society, and when Marie Curie visited SCC's plants in Pennsylvania five years later the Society counted 96 members.[542] In 1932, when radium cost $70,000 per gram, the USBM estimated there were 710 medical radium users in the U.S.[543] But the following year, the price of radium began plummeting when radium produced in Canada entered the market, setting off a price war between Belgian and Canadian suppliers that ended in 1938 when they agreed to form a cartel that set the price at $25,000 per gram.[544] With radium so much more affordable the number of private practitioners and hospitals engaged in radium therapy sharply increased, peaking in 1964 when there were about 3,600 medical radium users in the U.S.[545] By then, artificially produced radioactive material and other radiation therapy modalities such as the use of accelerator-produced radiation began eroding radium's foothold in radiation therapy; another contributing factor was the concern of public health agencies about improper storage, handling, and integrity of medical radium sources, especially the risk of radium leaking from such sources causing contamination.[546] These concerns led the U.S. Public Health Service to encourage medical radium users to replace radium with alternative sources and modalities, and federal and state initiatives were mounted to collect leaking and unwanted radium sources for disposal.[547] As a result, the medical use of radium that had grown in the early part of the 20th century — growth that in the beginning had been stimulated by the SCC — diminished. By the 1960s, the shrinking market for radium coupled with the increasing cost to dispose unwanted radium made it a financial liability. For example, in 1995 it cost as much as $5,000 to dispose three 15-milligram radium sources that, in 1920, would have cost $5,400 to purchase.[548] In the space of little more than six decades radium went from, as Landa wrote, "buried treasure to buried waste."[549]

While its production of radium lasted from only 1913 to 1922, a brief existence that might be taken as a sign of insignificance, the SCC was no ordinary commercial enterprise. Production of radium was the first nuclear industry. The mining and milling practices of the radium era served as forerunners of today's uranium industry which provides materials for nuclear weapons and nuclear power. The use of radium in medicine provided a basis for modern radiation therapy, and the early, often tragic experiences with occupational exposure to isolated radium salts served as a foundation for the modern science of radiation protection. SCC was the first American company to produce radium, became the world's largest producer, and started a robust domestic demand for medical radium. Medical radium paved the way for today's expanded use of radioactive materials in nuclear medicine and radiation therapy. These are the true legacies of the Standard Chemical Company and its founders, the remarkable brothers and undertakers-turned-industrialists, Joseph M. and James J. Flannery.

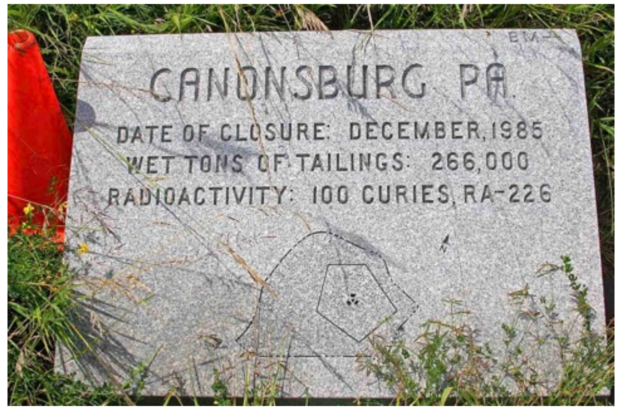


10.1 Left, Uravan during the 1950's uranium boom. Compare to Figure 3.16. *RHS* 10.2 Right, in this view, the Uravan site is nearing completion of remediation. The two remaining buildings, the white two-story Standard Chemical Company boarding house and the Uravan recreation hall, were later demolished. *RHS*



10.3 Left, the Vitro mill in Canonsburg, ca. 1950s. The view is from North Strabane looking south. *JTH* 10.4 Right, in June 1984, the vacant Canonsburg Industrial Park. *USDOE*

10.5 A 2004 view of the Canonsburg mill site after remediation, compare to Figure 10.3. *JOL*



10.6, 10.7 Warning sign on the Canonsburg perimeter fence and one of the two granite monuments inside the Canonsburg perimeter fence. *JOL*

10.8 Top left, the Vanadium/Flannery/Parkvale Building in 2013. Compare to Figure 1.17. *JOL*
10.9, 10.10 What does one do with an old bank vault? The University of Pittsburgh English Language Institute re-purposed it into a student lounge. *JOL*

Chapter 11: Markers

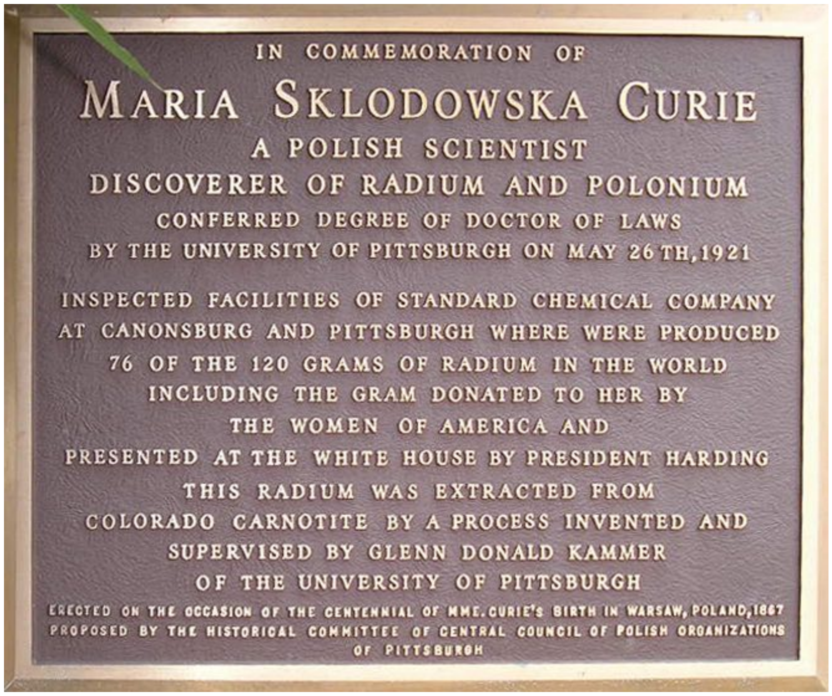
"We are proud of their accomplishments."

In 1967, the Historical Committee of Central Council of Polish Organizations of Pittsburgh sponsored creation of a plaque commemorating the 100th anniversary in 1967 of the birth of Marie Curie, her visits to the Standard Chemical Company plants in Canonsburg and Pittsburgh, its role in the making of the gram of radium donated to her by the Women of America presented to her by President Harding, and Glenn Donald Kammer, a University of Pittsburgh alumnus, who supervised its production (figure 11.1).

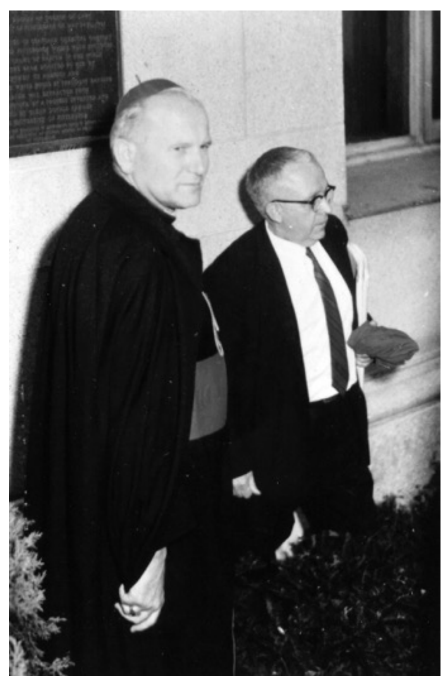
The plaque was installed at the entrance to the University of Pittsburgh's Allen Hall. Once home of the Mellon Institute of Industrial Research, Allen Hall has been designated an Historical Landmark by the Pittsburgh History and Landmarks Foundation. Named after physics Professor Alexander J. Allen, it houses the university's Department of Physics and Astronomy. In September 1969, the plaque was officially unveiled by the visiting Archbishop of Krakow Poland, Karol Józef Cardinal Wojtyla (figures 11.2 & 11.3). In 1978, the College of Cardinals elected him to the Papacy and he took the name, John Paul II. His role in unveiling the plaque may have been brief, a cameo, but in doing so he too became a part of the story of James and Joseph Flannery and their Standard Chemical Company.

The Allen Hall plaque is a handsome reminder of Marie Curie, university alumnus Glenn D. Kammer, and the Standard Chemical Company, but missing is acknowledgement of the role of the Flannery brothers. This was addressed in 2018 when the University of Pittsburgh installed a Pennsylvania Historical and Museum Commission (PHMC) marker near the Allen Hall plaque commemorating the first commercial production of radium by the Standard Chemical Company and naming James J. and Joseph M. Flannery as its founders (figure 11.4).

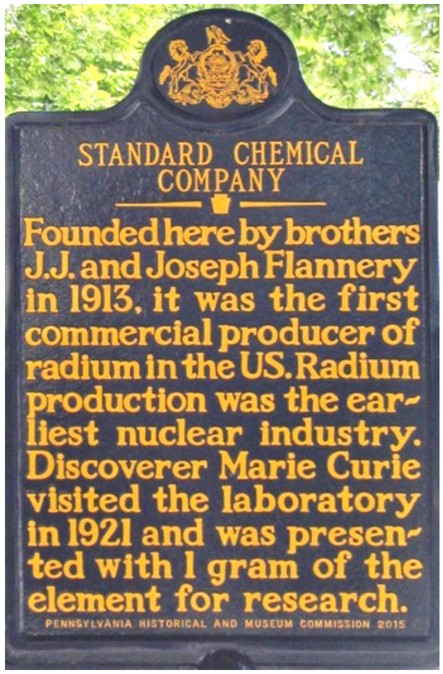
The marker was dedicated in November 2018. Pittsburgh's National Public Radio covered the dedication.[550] The ceremony was moderated by Michael Sheetz, Certified Health Physicist (CHP), director of the university radiation safety office, and featured presentations by David Allard, CHP, director of the Pennsylvania Bureau of Radiation Protection, about the history of radium in Pennsylvania; Joel Lubenau about the Flannery brothers and their radium and vanadium enterprises; and Andrew Masich, about the Pennsylvania Historical and Museum Commission. Many of the Flannery descendants were present and Sara (Sally) Flannery Hardon, great-granddaughter of James Flannery, spoke on their behalf. She said of the Flannery brothers, "They may not be as well-known as the Carnegies, the Westinghouses, and the Fricks, but we are proud of their accomplishments, which had lasting relevance, from steel alloys that are still used today to the development of atomic energy"[551] (figure 11.5).



11.1 The Historical Committee of Central Council of Polish Organizations of Pittsburgh plaque mounted on the building wall at the entrance to Allen Hall, University of Pittsburgh. *JOL*



11.2, 11.3 On September 20, 1969, the plaque was officially unveiled in a ceremony presided over by the Archbishop of Krakow, Cardinal Wojtyla, who, in 1978, became Pope John-Paul II. *CLP*



11.4 The Pennsylvania History and Museum Commission historical marker. It is in front of and close to the Allen Hall building plaque, the two nicely complimenting each other. *JOL*

11.5 Participants in the PHMC marker dedication, left-to-right, Michael Sheetz, David Allard, Sara (Sally) Flannery Hardon, Andrew Masich, and Joel Lubenau. *UP2*

Acknowledgements

Joel Lubenau's introduction to the SCC occurred in July 1963 when, as a green U.S. Public Health Service officer detailed to the Pennsylvania radiation control program, he was sent to Pittsburgh to investigate a report of radioactive property found at an auction house. It came from the estate of a gentleman who lived in Dormont, a suburb of Pittsburgh. His name was Arthur L. Miller, once employed by SCC. His house was — no surprise — contaminated by radium that had to be remediated. Little did Joel know at the time he would encounter Miller's name and that of the SCC again and again.

After receiving his Ph.D. in soil science, Edward (Ed) R. Landa joined the U.S. Geological Survey (USGS). He was assigned to Denver, Colorado where the USGS was assisting the state in assessing former radium mining and production sites. To better understand what went on in that era Ed became a miner himself by digging into newspapers, technical journals, Congressional records, and other sources to reconstruct the story of America's "First Nuclear Industry." The wealth of information he uncovered became the basis for "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry" published in 1987 by the Colorado School of Mines. Ed's monograph became and remains the primary reference on American radium production. Standard Chemical Company (SCC), of course, was a prominent part of his monograph.

We met for the first time at a meeting of the Baltimore-Washington Chapter of the Health Physics Society. We were intrigued by how much new information about SCC had emerged since Ed's landmark monograph on the history of radium production in America. For example, about 1995, James (Jim) Yusko and Joel visited Oak Ridge, Tennessee for a technical committee meeting. At the time, Jim was the manager of the Pennsylvania Bureau of Radiation Protection's Southwest Regional Office in Pittsburgh and was well acquainted with the SCC history in the region. While in Oak Ridge we visited Paul Frame who curates the Health Physics Historical Instrumentation Museum Collection of the Oak Ridge Associated Universities Foundation. Paul informed us he had just received a new item but we would have to visit the hot lab to see it because it was contaminated with radium. It was an album of photos illustrating SCC's operations in Colorado and Pennsylvania most of which we had not before seen. The Rutgers University Radiation Safety Office had donated the album but its earlier provenance was unknown. It was bound in leather and labeled in gold letters with company's name which suggested the album was assembled for SCC's corporate office in Pittsburgh to show to visitors. Then, in 2002 Umetco Minerals Corporation published a history of Uravan that covered SCC's presence in the Uravan area. In 2007, the Rimrocker Historical Society published a lavishly illustrated book about SCC that included personal recollections of SCC workers and their families describing what it was like to work and live there. More information came to light in 2010 when Peter Vogt cold-called Joel to tell him about SCC photos and ephemera that had been collected by his grandfather, Louis F. Vogt, the manager of the Canonsburg plant. In Pittsburgh, archivist David Grinnell introduced Joel to Sarah (Sally) Flannery Hardon, great-granddaughter of James. J. Flannery and to John G. Flannery, Joseph M. Flannery's grandson. Both shared their knowledge of their family. Sally, the family historian, has donated family ephemera to the Senator John Heinz History Center (HHC). In 2012, John loaned Joel a pair of photo albums compiled by Albert D. Riley, a SCC engineer, depicting SCC scenes in Colorado accompanied by detailed typed captions and explanations making it, in effect, a Rosetta Stone for understanding SCC's operations in Colorado. John later donated the albums to the HHC. Given these newly discovered and exciting finds we wondered, would a book devoted to SCC be in order?

While we are well experienced in writing and editing technical journal articles and scientific committee and government reports — even lengthy ones — creating a book manuscript would be a new experience. We sought the advice of two authors, Robert (Bob) Wolke and J. Samuel (Sam) Walker For many years, Bob, University of Pittsburgh Emeritus Professor of Chemistry, wrote a weekly column for the *Washington Post* about the science of cooking which led to popular commercial books on it and related subjects. Sam, distinguished historian, was the Nuclear Regulatory Commission official historian; university press imprints have published his many books. Their counsel about advantages and disadvantages of commercial and university presses was invaluable. Additionally, Sam reviewed and commented on the manuscript encouraging us in the process. Sam and Bob, thank you so very much.

Joel's wife, Anne, offered to serve as an "in-house" editor. In addition to a degree in chemistry she is a voracious reader of books on American political and European history. She is a tough editor. Thank you, Anne.

While the title page bears our names as authors many other individuals contributed to this book. We wish to gratefully acknowledge their timely assistance, comments, and suggestions given during the course of this project. It is with some trepidation that we list them for fear of failing to name them all. If we have, we apologize for our fallible memories (and note-taking).

Librarians, archivists, and members of historical societies are unsung heroes. They have been transforming our library and institutional collections to digital formats, no small task, and, at the same time, responding to requests for assistance. They have been unfailingly helpful even when confronted with inquiries seemingly impossible to answer. The following is a list of institutions whose collections and staffs were invaluable resources: the Interlibrary Loan staff of the McKeldin Library of the University of Maryland; Beth Lander, College of Physicians of Philadelphia Medical History Library; Marilyn Holt, Carnegie Library of Pittsburgh Pennsylvania Department; Julia Corrin, Carnegie Mellon University; Brian Butko, Anne Madarasz, Sierra Green, and Matthew Strauss, Detre Library and Archives, Senator John Heinz History Center; Mathew Harbison and Martha Graham, Legacy Center, Drexel University College of Medicine; David Grinnell and Zachary L. Brodt, University of Pittsburgh Archives Service Center; Kimberly A. Kirk, University of Pennsylvania School of Medicine; Edward H. Lybarger, Pennsylvania Trolley Museum Miller Library; Ed Wolf and Dorothy Stenzel, Bridgeville (Pennsylvania) Area Historical Society; Sandra Fye, National Museum of Nuclear Science and History; Tara C. Craig, Rare Book and Manuscript Library, Columbia University; Hillary Kativa, Science History Institute Othmer Library of Chemical History; Linda P. Gross, Hagley Museum and Library; Jane Thompson, Rimrocker Historical Society; Chris Miller, Interpretative Association of Western Colorado; Stephen Sinon, LuEsther T. Mertz Library of the New York Botanical Garden; Robert Vietrogoski, Rutgers University Libraries; Rachel F. Lokitz, Oak Ridge Associated Universities; Lisa Karam, Bert Coursey, Ronald Colle and Michael T. Unterweger, National Institute of Standards and Technology; Joan K. Green, Stark County District Library (Canton Ohio); Jim Orr, The Henry Ford; Chris Ritter, Antique Automobile Club of America Library and Research Center; Meg Fairfax Fielding, Maryland State Medical Society; Elaina Vitale, Niels Bohr Library & Archives, American Institute of Physics; Cheryl Gass, Saint John Regional Hospital, Saint John, New Brunswick; Sandra McKeown, Bracken Health Sciences Library, Queen's University, Kingston, Ontario; and Natalie Pigeard-Macault, Musée Curie, Paris.

We are also indebted to the staffs of the Frank Saris Public Library in Canonsburg, Pittsburgh History and Landmarks Foundation, Sewickley Public Library, Sewickley Valley Historical Society, Denver Public Library, Yale University Sterling Memorial Library, State Library of Pennsylvania, and the libraries of Bryn Mawr College, Carnegie Mellon University, Harvard University Radcliffe Institute for Advanced Study, Hunter College of the City University of New York, Lehigh University, Mt. Holyoke College, Simmons College, Smith College, University of Wyoming American Heritage Center, Vassar College, and Wellesley College.

The Health Physics Historical Instrumentation Museum Collection of the Oak Ridge Associated Universities Foundation, which chronicles the scientific and commercial history of radioactivity and radiation, is an extraordinary resource. We thank Paul Frame, its curator, who was unfailing in responding to our requests for additional information and photographs.

The 2018 installation and dedication of the Pennsylvania Historical and Museum Commission (PHMC) marker at the University of Pittsburgh Allen Hall truly was a team effort: Karen Galle, PHMC historical marker program coordinator, shepherded the application submitted by Sara (Sally) Flannery Hardon. At the university, David Grinnell, archivist, found temporary storage space for the marker (not a small thing) until its installation; Denise Doswell, Ronald Leibow, Dan Fisher, Canard Grigsby, and Tim Smithco, facilities management, installed it; Kimberly Barlow, communications manager, coordinated media contacts and photography for the dedication, and Kelly Hardon (Sara Flannery Hardon's daughter) and Michael Sheetz, radiation safety office, helped plan it. The Department of Physics and Astronomy, chaired by Arthur Kowoski, hosted the event. Thank you.

Many individuals made available their personal collections and unstintingly shared their knowledge especially David J. Allard, Elizabethtown, Pennsylvania; the late James T. Herron, Canonsburg, Pennsylvania; Rose Marie Pratt, New York City; John C. Villforth, Rockville, Maryland; and the late Sydney W. Porter, Jr. Also, Peter S. Vogt, formerly of Cabin John, Maryland and now Hendersonville, North Carolina. Peter, a documentary film maker and grandson of Louis Fenn Vogt, later donated his SCC photos and related ephemera to the Senator John Heinz History Center, Pittsburgh and donated a virtually pure specimen of the carnotite mineral from Paradox Valley to the Rimrocker Historical Society of Western Montrose County, Colorado.

Dr. Jesse Aronowitz, University of Massachusetts Memorial Medical Center, provided comments on the medical applications of radium. Jerry Rosen and the late Herman Cember, both former Radiation Safety Officers at the University of Pittsburgh, provided insights into the role of the university at SCC. Dr. Roger Robison, Bloomington, Indiana, arranged for Joel to attend 100th Anniversary meeting of the American Radium Society (ARS) in Philadelphia in 2016 and made available copies of ARS ephemera concerning its history. Philip Egidi, formerly of Denver Colorado, collected a splendid specimen of carnotite from the same area of Paradox Valley where SCC had its mines; part of it now resides the Senator John Heinz History Center. Health physicist Richard E. Toohey enlightened us on the chemical behavior of radium in humans, and James G. Yusko, a Pittsburgh health physicist, recalled his experiences overseeing the remediation of the Canonsburg site. Maria Rentetzi, University of Athens, shared her insights into the history of the use of radium and early radium research and development. Janice K. Shepherd, a member of the Colorado Archeological Society, pointed us to the website for Colorado Historical Newspapers.

Richard F. Mould, United Kingdom, has written extensively on the early history of the medical use of radium and X-ray but equally important he has been generous in encouraging others in doing the same and sharing his knowledge.

Often intermediaries provide bridges to new contacts. Early on, Anne-Marie Lubenau, Joel's daughter, an architect then living in Pittsburgh suggested contacting the Pittsburgh History and Landmarks Foundation. That led, in turn, to contacts with other western Pennsylvania libraries and historical societies including the Senator John Heinz History Center where David Grinnell connected Joel to Sally Flannery Hardon and John Flannery.

Thank you, all.

Chapter Notes

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[1] George T. Fleming, ed., *History of Pittsburgh and Environs* (New York and Chicago: The American Historical Society, 1922), volume 2, 57-75.

[2] Fleming, ed., *History of Pittsburgh and Environs,* volume 2, 71-72.

[3] Fleming, ed., *History of Pittsburgh and Environs,* volume 2, 165.

[4] Fleming, ed., *History of Pittsburgh and Environs,* volume 2, 168.

[5] Fleming, ed., *History of Pittsburgh and Environs,* volume 2, 90-91, 165.

[6] Fleming, ed., *History of Pittsburgh and Environs,* volume 2, 93, 170-176.

[7] Fleming, ed., *History of Pittsburgh and Environs,* volume 2, 168-169.

[8] Howard V. Worley, Jr., *Pittsburgh Inclines and Street Railways,* (Saxonburg: Howdy Productions, 2005), 3-33.

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[10] Dan Rooney and Carol Peterson, *Allegheny City: A History of Pittsburgh's North Side,* (Pittsburgh: University of Pittsburgh Press, 2013), Chapter 7, Annexation: 1907, 130-144, https://muse.jhu.edu/, (accessed December 31, 2017).

[11] First National Bank at Pittsburgh, *The Story of Pittsburgh* (Pittsburgh: First National Bank at Pittsburgh, August 1919 – September 1930, seventeen volumes).

[12] First National Bank at Pittsburgh, *The Story of Pittsburgh*, volume one, number two.

[13] "Pitt Degree Conferred on Mme. Curie," *The Gazette Times*, May 27, 1921. The text of Dr. Holland's speech is preserved at in Chancellor of the University of Pittsburgh, William Jacob Holland, Administrative Files, Collection Number: UA.2.10.1891-1901, ULS Archives Service Center, University of Pittsburgh Library System, Pittsburgh PA.

[14] "The Death Roll, Mrs. Ellen Kirwan Flannery," *Pittsburgh Gazette,* September 3, 1897.

[15] "Mrs. Lydia B. Kraeling," *Pittsburgh Daily Post,* January 14, 1914. Lydia B. Flannery married Henry Kraeling. For information about James J. Flannery see Alexander P. Moore, ed., *The Book of Prominent Pennsylvanians: A Standard Reference* (Pittsburgh: Leader Publishing Company, 1913), 77; Anon., *The National Cyclopedia of American Biography, Volume XXIII* (New York: James T. White & Company, 1933), 231 and "Death Takes Bank Head in Oakland," *Pittsburgh Dispatch*, March 8, 1920.

[16] "The Death Roll, Mrs. Ellen Kirwan Flannery," *Pittsburgh Gazette,* September 3, 1897; Ross Mullner, *Deadly Glow: The Radium Dial Worker Tragedy* (Washington DC: American Public Health Association, 1999), 24. Mullner misidentifies Ellen Flannery as "Eleanor"; "Peter K. Flannery Dead in Swissvale," *Pittsburgh Post-Gazette,* August 28, 1911, "John S. Flannery," *The Pittsburgh Catholic,* December 23, 1915; Anon. *The National Cyclopedia of American Biography, Volume XXIII*, 231-232; Fleming, *History of Pittsburgh and Environs*, volume 3, 804-808. Additional information about Ellen, John, and Peter Flannery was obtained from "Find a Grave," https://www.findagrave.com, (accessed December 22-17, 2017).

[17] "Death Takes Bank Head in Oakland," *Pittsburgh Dispatch,* March 6, 1920.
[18] "New Councilmen," *Pittsburgh Daily Post*, May 12, 1877.
[19] "Ward Meetings," *Pittsburgh Daily Post*, August 30, 1880.
[20] "Renziehausen Defeated," *Pittsburgh Daily Post,* February 16, 1881.
[21] "Death and Destruction," *Pittsburgh Daily Post,* December 5, 1885.
[22] "Undertakers to Go To-day," *Pittsburgh Dispatch,* June 2, 1889; *"The Undertakers Move," Pittsburgh Daily Post*, June 3, 1889.
[23] "Couriers Return," *Pittsburgh Daily Post,* June 3, 1889.
[24] "Not All Serene," *Pittsburgh Dispatch,* June 8, 1889; "A Bitter Fight," *Pittsburgh Dispatch*, June 9, 1889; "Undertakers' War," *Pittsburgh Dispatch,* June 10, 1889.
[25] "Notice is hereby given…," *Pittsburgh Daily* Post, November 29, 1900; Moore, *The Book of Prominent Pennsylvanians: A Standard Reference*, 77; Charles A. Rook, ed., *Western Pennsylvanians, A Work for Newspaper and Library Reference,* (Pittsburgh: Western Pennsylvania Biographical Association, 1923), 413,423.
[26] "Peter K. Flannery," *Pittsburgh Press,* August 28, 1911.
[27] Arthur L. Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," in Asher J. Finkel, ed., *ANL-7461 Health Division Gamma-Ray Spectroscopy Group Research Report July 1965 through June 1968,* (Argonne: Argonne National Laboratory, July 1968), 91-100.
[28] Edward White, ed., *Pittsburgh The Powerful,* (Pittsburgh: The Industry Publishing Company, 1907), 59; Pennsylvania Department of State records of incorporation of the Flannery Bolt Company, Collection of Joel O. Lubenau.
[29] U.S. Patent No. 753,329, March 1, 1904.
[30] First National Bank at Pittsburgh, *The Story of Pittsburgh*, volume one, number two.
[31] Roscoe Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh." *The Pittsburgh Press, The Press World of Today,* July 27, 1930.
[32] Anon. *The National Cyclopedia of American Biography, Volume XXIII*, 231-232; Anon., "A Sketch of the Life and Work of Joseph M. Flannery," Radium 14:6 (March 1920), 100.
[33] Anon. "Vanadium," *American Vanadium Facts*, 2:2 (April 1912), no page number.
[34] "Vanadium Company Sold for $7,000,000," *The New York Times*, August 23, 1916.
[35] M. K. Helouis, "Vanadium, its Alloys and their Applications," *Ball de la Soc. d'Encouragement*, (June 1896), 904-908, in a review of Helouis' paper in *The Journal of the Society of Chemical Industry*, 15 (Sept. 30, 1898), 765.
[36] George L. Norris, "Vanadium Alloys," *Journal of the Franklin Institute* 71:6 (June 1911), 564.
[37] Baram D. Saklatwalla, "The Technical Chemistry of Vanadium," *Journal of Industrial and Engineering Chemistry* 14:10 (October 1922), 968; John O. Arnold, "Recent Advances in Scientific Steel Metallurgy," *Nature* 91:2264 (March 20, 1913), 70-72.
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[39] James E. Lounsbury, "Famous Pittsburgh Industries." *The Crucible* 22 (May 1938), 109.

[40] Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh."
[41] James G. Steese, "Coasting From Sky to Sea," *Bulletin of the Pan American Union* 40 (January-June 1915), 37-47.
[42] Lawrence A. Clayton, *Peru and the United States: The Condor and the Eagle*, (Athens: University of Georgia Press, 1999), 77, 86-87.
[43] Rosemary Thorp and I. G. Bertram, *Peru, 1890-1977: Growth and Policy in an Open Economy* (New York: Columbia University Press 1978), 84.
[44] D. Foster Hewett, "Vanadium-Deposits in Peru." *Transactions of the American Institute of Mining Engineers*, 40 (1910), 276-277.
[45] Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh."
[46] Foster Hewett, "A New Occurrence of Vanadium in Peru," *Engineering and Mining Journal* 82:9 (Sept. 1, 1906), 385.
[47] Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh."
[48] Letter, D. Foster Hewett to Joseph M. Flannery, February 27, 1906, Box 48, Acc. #5058, Vincent E. McKelvey papers, American Heritage Center, University of Wyoming.
[49] Harry Adolf Neeb was born April 9, 1850 in Pittsburgh. After attending city schools and the University of Pittsburgh he joined his father's newspaper business. His association with the Flannerys dates to the Flannery Bolt Company and continued to the Standard Chemical Company, see George T. Fleming, *History of Pittsburgh and Environs*, volume 5, 188-189.
[50] Printing errors in the following references contribute to confusion about the incorporation date and company's capitalization: Anon, "New Corporations, New Jersey" National Corporation Reporter 32:1 (February 22 1906), 15, lists the capitalization as $500,000; Walter H. Weed, ed., *International Edition –The Mines Handbook, An Enlargement of the Copper Handbook* vol. XIII (New York: W. H. Weed, 1918), 1282 reported the original capitalization correctly as $700,000 but erroneously listed the incorporation year as 1916; *The New York Times* reported it as $700,000, see "Vanadium Company Sold for $7,000,000" August 23, 1916; Anon., "Vanadium-An Industrial Romance," Chemical Age 1:7 (December 25, 1919), 304-305 states the transaction between Flannery and Fernandini resulted in Fernandini receiving "One-tenth of the stock, or $70,000 par value."
[51] Letter, D. Foster Hewett to Joseph M. Flannery, May 24, 1906, Vincent E. McKelvey Papers.
[52] Both Bravo and Hewett recommended naming the ore in honor of Patron, see D. Foster Hewett, "A New Occurrence of Vanadium in Peru," 385; Newspaper Clipping, Jose J. Bravo, "El vanadio de Minasragra," *El Commerce* (Lima), September 20, 1906. Vincent E. McKelvey Papers.
[53] William B. Parker, ed., "*Peruvians of Today*," (Lima, Peru: Southwell Press, 1919), 95-96.
[54] Anon. "American Beauty." *Time,* November 21 1949.
[55] Anon. "A Sketch of the Life and Work of Joseph M. Flannery," 99-107.
[56] Anon. "Vanadium--An Industrial Romance," 304-305.
[57] Newspaper Clipping, James Hay, Jr., "He Filled His Carpet Bag with Gold." Undated, Vincent E. McKelvey Papers. The newspaper name is missing.

[58] Merle Crowell, "Keep your eyes on Replogle," *The American Magazine* 86 (January 1920), 152-154.
[59] Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh."
[60] W.H. Weed, *International Edition –The Mines Handbook, An Enlargement of the Copper Handbook vol. XIII*, 1282. Fernandini is listed as first vice-president.
[61] "The Romance and Marvels of Vanadium," *The New York Times*, July 14, 1907. A clipping of this article that is annotated, probably by Hewett, is in Box #48 of the McKelvey Papers.
[62] Anon. "Our New Plant," *American Vanadium Facts*, 4:2 (April 1914): 2; Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh," *The Pittsburgh Press, The Press World of Today,* July 27, 1930.
[63] Born Byramji Dorajbi Saklatwalla in Bombay, India, Beram Saklatwalla was a Persian Parsee whose family had moved to India.
[64] Anon. "Saklatwalla's Step." *Pittsburgh Bulletin Index* (Sept. 26, 1935).
[65] Baram D. Saklatwalla, "The Vanadium Corporation of America and Its Predecessor, The American Vanadium Company," *Journal of Industrial and Engineering Chemistry* 17:3 (March 1925), 321-324; Baram D. Saklatwalla, "The Ferro-Alloy Industry, *Journal of Industrial and Engineering Chemistry* 14:9 (September 1922): 862-863.
[66] Anon. "Our New Plant" *American Vanadium* Facts, 2-6; Fleming, *History of Pittsburgh and Environs*, volume 4, 60-61, Angelique Bamburg, "Up Front, Architecture Around Us, Frederick J. Osterling's Neighborhood: His residential Designs in Brighten Heights," *Western Pennsylvania History* 102:5 (Spring 2019), 8-9.
[67] Robert Casey, *The Model T – A Centennial History* (Baltimore: Johns Hopkins Press, 2008), 16-17.
[68] Charles Sorenson, *My Forty Years With Ford* (New York: W. W. Norton & Company, 1956), 98-99; James T. Casey, *The Model T - A Centennial History,* 19. According to a 1920 biography of Joseph Flannery, he convinced Ford of the superior qualities of vanadium steel by taking Ford cars made of the alloy to a high cliff and "in the presence of Mr. Ford's staff, had them literally thrown off the precipice." Ford's staff found that while badly bent and twisted the car's vanadium steel components did not break, see Anon., "A Sketch of the Life and Work of Joseph M. Flannery," 102. It is a grand tale about convincing Ford of the merits of vanadium steel but other accounts, including by Ford, show he came to this conclusion through other means. Ford recalled he had first learned of the superior qualities of vanadium steel after witnessing a severe accident in an auto race that wrecked a French-made racing auto and found some of the wrecked steel while badly bent were unbroken. The French mechanics told him they were made of vanadium steel, see Henry Ford and Samuel Crowther, *My Life and Work* (Garden City and New York: Doubleday, Page and Co.), 65-66. Ford misremembered the date and place of the race describing it as 1905 at Palm Beach. More likely it was in January 1904 at Daytona Beach where a French Panhard lost a wheel on a turn and was wrecked, see F. Ed. Spooner, " The Florida Race Fleet," *The Horseless Age,* 13:5 (February 3, 1904), 143. Finally, by 1905 Ford's staffs had themselves learned of vanadium steel at engineering conferences and by perusing technical

journals, see Casey, *The Model T – A Centennial History* 19. Smith's 1906 discussions with Ford confirmed Ford's belief in vanadium steel.

[69] Patrick D. Curran, e-mail message to Lubenau, October 16, 2016. Mr. Curran is a grandson of John Patrick Curran, one of the three Curran brothers engaged in vanadium ore mining in Colorado. The Curran brothers were associated with the Flannery brothers in the production of vanadium; T. F. V. Curran was an assistant to Joseph Flannery at the AVC.

[70] H. Riall Sankey and J. Kent Smith, " Heat Treatment Experiments with Chrome-Vanadium Steel."

[71] Sorenson, *My Forty Years With Ford,* 98.

[72] Sorenson, *My Forty Years With Ford,* 98-99.

[73] Edward T. Heald, *Stark County Story, Volume. III, Industry Comes of Age 1901-1917*, (Canton: Stark County Historical Society, 1952), 34.

[74] Heald, *Stark County Story, Volume III, Industry Comes of Age 1901-1917,* 36-37.

[75] "Steel Men in Canton." *The (Canton) Repository*, March 28, 1907.

[76] Calculated using the "Federal Reserve Bank of Minneapolis Consumer Price Index (Estimate) 1800-," http://www.minneapolisfed.org/community_education/teacher/calc/hist1800.cfm?&TC=.

[77] Advertising Brochure, *Vanadium Steel, The United Steel Co*., (Columbus: The Champlin Press, 1907), The Collections of The Henry Ford.

[78] Thomas J. Misa, *A Nation of Steel, The making of modern America 1865-1925*, (Baltimore: Johns Hopkins University, 1995), 226, Casey, *The Model T – A Centennial History,* 92.

[79] Misa, *A Nation of Steel, The making of modern America 1865-1925*, 227.

[80] Anon. "A Sketch of the Life and Work of Joseph M. Flannery," 101.

[81] Anon. "Wheeling Mold & Foundry Company, W. Va.," *American Vanadium Facts*, 1:3 (May 1911), no pagination; Anon. "Vanadium Steel for the Panama Canal," *American Vanadium Facts*, 1:7 (September 1911), no pagination; Anon. "Vanadium Steel Castings for the Panama Canal," *American Vanadium Facts*, 1:9 (November 1911), no pagination; Anon. "Vanadium Steel for the Emergency Dams of the Panama Canal," *American Vanadium Facts* (May 1913), 4-8.

[82] The June 1911 issue of *American Vanadium Facts* (1:4) was marked as "Convention Issue Railway M.M. and M.C.B Convention." The headline was shorthand for the American Railway Master Mechanics (M.M.) Association and the [Railway] Master Car-Builders (M.C.B.) Association; Anon. "Power in the Air," *American Vanadium Facts* 1:5 (July 1911), no pagination; Anon. "Vanadium Steel Armor Plate," *American Vanadium Facts* 1:8 (October 1911), no pagination; Anon. "Hendee Manufacturing Company, Springfield, Mass," *American Vanadium Facts* 2:1 (March 1912), no pagination.

[83] Anon. "Vanadium in 1913 Cars and Trucks," *American Vanadium Facts* 2:11 (January 1912), 2-4.

[84] Examples titles by J. Kent Smith and Call Numbers of the Manuscripts and Archives, Hagley Museum and Library include *Vanadium Its Services in Automobile Manufacture*, PAM 95.302;

Vanadium, 'The Master Alloy,' Its Services in Railway Steels, PAM 95.303; *Application of Vanadium to Steel and,* PAM 95.304; *Estimation of Vanadium in Steels, Alloys, Ores, Brasses, Bronzes, Cupro-Vanadium, Etc*., PAM 95.305; *Vanadium, 'The Master Alloy,' In Cast Iron,* PAM 95.306; *Vanadium, 'The Master Alloy,' Case Hardening Process*, PAM 95.307; *The Present Source and Uses of Vanadium,* PAM 95.308; *Vanadium, Its Services in Engineering Steels,* PAM 95.309; *Alloy Steels for Motor Car Construction,* PAM 95.310. The most comprehensive brochure insofar as technical content is *Vanadium Steels, Their Classification and Heat Treatment with Directions for Application of Vanadium to Steel and Iron,* call #.A5055, Imprints,-TRADE,. Also, J. Kent Smith, *Vanadium, Its Services in Steel Making; Vanadium, Its Services in Railroad Practice,* Special Collections, University of Pittsburgh Hillman Library.

[85] Anon. "Two New Vanadium Alloys for Non-Ferrous Metals," *American Vanadium Facts* 1:3 (May 1911), no pagination.

[86] "A Tougher Armor for Our Warships," *The New York Times*, July 8, 1907.

[87] Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh."

[88] Anon. "The Vanadium - The Carlsbad of America" (advertisement), *Literary Digest* 41:13, September 26, 1910, 522.

[89] Norris, "Vanadium Alloys," 564; Anon., "Vanadium,"*The Americana Supplement* 2 (1911), 1139.

[90] American Medical Association. "The Propaganda for Reform, Turner Obesity Cure." *Journal of the American Medical Association* 58:25 (June 22, 1912), 1961.

[91] Vanadium Chemical Company Collection, ca. 1912, Historical Medical Library of the College of Physicians of Philadelphia.

[92] Many Comforts Under One Roof," *Pittsburgh Daily Post,* June 16, 1901.

[93] Walter C. Kidney. *Pittsburgh's Landmark Architecture The Historical Buildings of Pittsburgh and Allegheny* County (Pittsburgh: Pittsburgh History and Landmarks Foundation, 1997), 245-246. Originally a twenty story building when it opened in 1902 the building gained another story in 1913 after Pittsburgh removed the "Grant's Hill Hump" lowering Grant Street and making the ground floor the new entrance level.

[94] Anne Madarasz, "The Vanadium Window," *Western Pennsylvania History* 94:4 (Winter 2011-12), 58-59.

[95] Sarah (Sally) Flannery Hardon, great-granddaughter of James J. Flannery, and John G. Flannery, grandson of Joseph M. Flannery, spent time working in the Vanadium Building and, in conversations with Lubenau, recalled the location of the window and other details.

[96] Anon., "90,000 Tons Vanadium Steel," *American Vanadium Facts* (advertisement) 3:3 (May 1913), 12 (rear cover); Anon. "The Production of Vanadium Steel in 1910," *American Vanadium Facts* 1:8 (October 1911), no pagination.

[97] Lawrence Clayton, *Peru and the United States: The Condor and the Eagle*, 87; Fleming, "Steel Girders from the Roof of the World, How Vanadium Came to Pittsburgh," *The Pittsburgh Press, The Press World of Today,* July 27, 1930.

[98] Anon. "Our New Vice-President and General Manager of Sales," *American Vanadium Facts*, 4:12 (February 1915), 6.
[99] "Vanadium Company Sold for $7,000,000" *The New York Times*, August 23, 1916.
[100] F. DeLucio, letter dated Sept. 22 1906 to Foster Hewett, Pittsburgh. The letter is in Box #48 of the McKelvey Papers.
[101] Richard F. Mould, *Annotated X-Ray Bibliography 1896-1945 also containing some references on nuclear physics, radioactivity, & nuclear medicine.* (Warsaw: Polish Oncological Society, 2014), 24-15.
[102] Entitled, "X-actly So!," the poem has been attributed to an anonymous author, Wilhelmina, published in 1896 in *Photography* magazine, see https://www.washingtonpost.com/archive/1995/11/08/x-marks-the-ray-that-can-peer-inside-the-body/283abaa1-13e0-4f31-a762-aec4aa9eb877/?utm_term=.7970e4ffa592; and https://filmlessradiography.wordpress.com/2009/12/16/x-actly-so/ (both accessed January 3, 2018).
[103] Marie Curie, *Pierre Curie*, (New York: MacMillan Company, 1923): 103.
[104] Pierre Curie, "Radioactive substances, especially radium, Nobel Lecture, June 6, 1905," 75, accessed January 4, 2018, https://www.nobelprize.org/nobel_prizes/physics/laureates/1903/pierre-curie-lecture.pdf.
[105] J. Samuel Walker, *Permissible Dose,* (Berkley: University of California Press, 2000), 4; Lawrence Badash, *Radioactivity in America, Growth and Decay of a Science,* Baltimore: The Johns Hopkins University Press, 1979), 26.
[106] Richard F. Mould, "Radium History Mosaic." *Nowotwory Journal of Oncology* 57 (2007): Supplement 4, 84.
[107] For more information on the "Radium Craze," see Badash, *Radioactivity in America, Growth and Decay of a Science*, 19-32.
[108] Arthur W. Goodspeed, "The Physical Properties of Radium," *Transactions of the College of Physicians of Philadelphia,"* Third Series, 43 (1921), 89; "University Notes," *Philadelphia Inquirer,* December 14, 1899; "Philadelphia's Contribution to Science," *Philadelphia Inquirer,* December 19, 1899.
[109] Charles Baskerville, *Radium and Radioactive Substances,* (Philadelphia: Williams, Brown & Earle, 1905), 115-116.
[110] Baskerville, *Radium and Radioactive Substances,* 115-141.
[111] Ross Mullner, *Deadly Glow: The Radium Dial Worker Tragedy,* (Washington: American Public Health Association, 1999), 24.
[112] Lounsbury, "Famous Pittsburgh Industries,"109.
[113] "Dr. de Alzugaray, A Chemist, is Dead," *The New York Times*, June 14, 1937.
[114] Ruth Brecher and Edward Brecher, *The Rays*, (Baltimore: The Williams and Wilkins Company, 1969), 159.
[115] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 63rd Cong., 2nd sess., 1914, 54.

[116] Brecher and Brecher. *The Rays*, 159.
[117] Brecher and Brecher, *The Rays,* 151-159.
[118] Roger E. Robison, "Historia medicinae, Howard Atwood Kelly (1858-1943): founding Professor of Gynecology at Johns Hopkins Hospital & pioneer American radium therapist" *Nowotwory Journal of Oncology* 60:1 (2010): 29e.
[119] Jesse Aronowitz, "Robert Abbe: Early American brachytherapist," *Brachytherapy* 4:10 (2012), 2.
[120] Richard F. Mould, "Radium History Mosaic, "*Nowotwory Journal of Oncology*, 57 (2007): Supplement 4, 99.
[121] Marie Curie, *Pierre Curie*, 99-100.
[122] Curie. *Pierre Curie*, 112-113.
[123] Badash, *Radioactivity in America, Growth and Decay of a Science*, 140.
[124] Badash, *Radioactivity in America, Growth and Decay of a Science*, 140.
[125] Edward R. Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," *Colorado School of Mines Quarterly* 82:2 (Summer 1987), 7-10.
[126] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 10.
[127] Stephen T. Lockwood, *Radium Research in America 1902-1914-1939,* (East Aurora NY: Roycroft Shop, 1939), Appendix 2, Souvenir 11. This book consists of a copy of the "Souvenir" presented to Marie Curie by the Buffalo Society of Natural Sciences when she visited Buffalo in 1921 plus an Appendix covering the period ending March 28, 1939; pagination is divided accordingly.
[128] Lockwood, *Radium Research in America 1902-1914-1939*, Appendix, 6-8.
[129] Curie, *Madame Curie*, 17, 111-112.
[130] Lockwood. *Radium Research in America 1902-1914-1939*, Souvenir, 3.
[131] Letters, Stephen T. Lockwood to Bertram B. Boltwood, January 23, 1911 and Bertram B. Boltwood to Stephen T. Lockwood, January 30, 1911, Box 2, Folder 60, MS 90, Bertram Borden Boltwood Papers, Manuscipts and Archives ,Yale University Sterling Memorial Library.
[132] Anon., "Personals," *American Machinist* 33, Part 1 (January 20, 1910), 139.
[133] Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 91; Anon., "A Sketch of the Life and Work of Joseph M. Flannery," 102.
[134] Mullner, *Deadly Glow The Radium Dial Worker Tragedy,* 24.
[135] Lounsbury, "Famous Pittsburgh Industries," 109.
[136] Anon., "A Sketch of the Life and Work of Joseph M. Flannery," 103.
[137] U.S. Congress, Senate, Committee on Mines and Mining, *Radium: Hearing before the Committee on Mines and Mining on S. 4405*, 63rd Cong., 2nd sess., 1914, 30.
[138] Albert D. Riley, Introductory notes, photos 87B, 85B, Albert D. Riley Photograph Albums,1910-c. 1921, volume one, PSS 68, Detre Library and Archives, Senator John Heinz History Center. The albums consist of Riley's typewritten notes and photographs. No pagination. Most of the photos are numbered but are not in sequence. In lieu of pagination, the photo numbers are used for citation.

[139] Riley, Introductory notes, Albert D. Riley Photography Album, volume 1; Roscoe Fleming, "Medicine From Ores," *Pittsburgh Post-Gazette* (August 10, 1920); Division of Corporations, State of Delaware, *The Standard Chemical Company Certificate of Incorporation*, March 5, 1911, 0027419, Roll 0039, Frame 1670.
[140] In November 1913, a SCC sales subsidiary, Radium Chemical Company (RCC), was incorporated, also in Deleware, having shareholders, stock distribution and capitalization very similar to the SCC, see Division of Corporations, State of Delaware, November 26, 1013, 0038530, Roll 0034, Frame 6387. Both SCC and RCC were organized on behalf of Flannery who for reasons of his own chose not to be identified in the creation filing.
[141] *Montrose [Colorado] Daily Press*, June 28, 1911; "Peter K. Flannery Dead In Swissvale," *Pittsburgh Post-Gazette,* August 28, 1911.
[142] Mullner, *Deadly Glow The Radium Dial Worker Tragedy*, 24.
[143] Introductory notes, Albert D. Riley Photography Album, volume 1. It is not known if any work was done by Helouis on the ore delivered to Cambridge Springs, Pennsylvania.
[144] Letter, George Lees to Bertram B. Boltwood, May 6, 1911, Bertram Borden Boltwood Papers.
[145] Letters, George Lees to The Dean, Lawrence Scientific School, Yale University, May 2, 1911; George Lees to Bertram B Boltwood, May 6, 1911; George Lees to Bertram B. Boltwood, May 27,1911; Bertram B. Boltwood to George Lees, June 1 1911; George Lees to Bertram B. Boltwood, June 14, 1911, Bertram Borden Boltwood Papers.
[146] Letter, Bertram B. Boltwood to George Lees, June 19, 1911, Bertram Borden Boltwood Papers.
[147] Letter, George Lees to Bertram B. Boltwood, June 20, 1911, Bertram Borden Boltwood Papers.
[148] Letter, Bertram B. Boltwood to George Lees, June 29, 1911, Bertram Borden Boltwood Papers.
[149] Letter, Rowland Bosworth to Bertram B. Boltwood, July 9, 1911, Bertram Borden Boltwood Papers.
[150] Letter, Rowland Bosworth to Bertram B. Boltwood, September 21, 1991, Bertram Borden Boltwood Papers.
[151] Letters, Joseph M. Flannery to Bertram B. Boltwood letter, October 7, 1911; Bertram B. Boltwood to Joseph M. Flannery letter, October 31, 1911, Bertram Borden Boltwood Papers. Although Boltwood indicated his willingness to enter a long-term agreement there is no evidence showing an agreement was finalized. Boltwood subsequently distanced himself from the SCC enterprise in favor of the U.S. Bureau of Mines-sponsored National Radium Institute.
[152] The unidentified person may have been Dr. W. A. Schlesinger from Heidelberg. Little is known about Schlesinger's turn at the Canonsburg plant except that he departed for Colorado where he formed his own company, Schlesinger Radium Company that later became the Radium Company of Colorado. Miller, "Personal Reminiscences of the Early History of the Radium

Extraction Industry in the U.S.A.," 92;. Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 21.

[153] Letter, Rowland S. Bosworth to Bertram B. Boltwood, January 31, 1911, Bertram Borden Boltwood Papers.

[154] In 1915, Bosworth was the physicist for the General Memorial Hospital, New York City, see Rowland S. Bosworth, "The Collection of Radium Emanation and its Preparation for Therapeutic Use," *Transactions of the American Electrochemical Society Twenty-Eighth General Meeting Panama-Pacific International Exposition San Francisco September 16-25, 1915* 28 (1915), 419-424.

[155] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 55.

[156] Maria Rentetzi, "The U.S. Radium Industry: Industrial In-house Research and the Commercialization of Science," *Minerva* 46 (2007), 450-451; Ramsey/Brill Letters, MS ADD 415, UCL Special Collections, UCL Archives, University College London, accessed March 24, 2017, http://archives.ucl.ac.uk/DServe/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=Show.tcl&dsqSearch=RefNo=='MS%20ADD%20415'&dsqDb=Catalog.

[157] Alexander Silverman, "Pittsburgh's Contribution to Radium Recovery," *Journal of Chemical Education* 27:6 (June 1950), 304; Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 92**.**

[158] Lounsbury, "Famous Pittsburgh Industries," 88-89.

[159] Lounsbury, "Famous Pittsburgh Industries." 110; Silverman, "Pittsburgh's Contribution to Radium Recovery, 304.

[160] Louis F. Vogt, "Radium —The Wonder Element," *Official Proceedings of the Railway Club of Pittsburgh* 21:7 (May 22, 1922), 144.

[161] Lounsbury, "Famous Pittsburgh Industries," 111

[162] Letter, Otto Brill to Bertram B. Boltwood, January 2, 1912, Bertram Borden Boltwood Papers. The year date, an obvious typing error, should be 1913.

[163] Letter, Bertram B. Boltwood to Otto Brill, January 20, 1913, Bertram Borden Boltwood Papers.

[164] The history of the international and U.S. standards can be found on the NIST website, accessed February 19, 2015, http://www.nist.gov/pml/general/curie/1913.cfm. In 1934, Otto Honigschmidt, after refining the value of the atomic weight of radium, prepared twenty new secondary standard radium sources, two of which became the new U.S. primary radium standards, see T. I. Davenport, W. B. Mann, C. C. McCraven, C. C. Smith, W. S. Connor, and W. I. Youdon, "Comparison of Four National Radium Standards," *Journal of Research of the National Bureau of Standards,* 53:5 (November 1954), 267-275.

[165] Anon., "American Radium," *The Mining Investor,* 71:2 (May 26, 1913), 23; Anon., "Shipping Radium Abroad. Pittsburgh Interest Sends First Consignment Direct to Paris," *Industrial World* 47:21 (May 26, 1913), 618; "Canonsburg Radium Shipped to Europe — Dr. Otto Brill, Austrian

Expert, Takes $60,000 Worth of Substance in Vest Pocket, London Hospitals Want It." (Canonsburg, PA) *The Daily Notes*, May 22, 1913.
[166] Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 94.
[167] Charles H. Viol, "First Pure Radium Salts Prepared in America," *Radium* 1:6 (September 1913), 8-9
[168] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 111; Anon., "Notes and Comments," *Radium* 2:1 (October 1913), 9.
[169] The SCC calibration certificates for the NBS sources, although radioactively contaminated, have been preserved by NIST.
[170] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 110-112.
[171] Lounsbury, "Famous Pittsburgh Industries," 110.
[172] Paul M. O'Rourke, *Frontier in Transition, A History of Southwestern Colorado.* (Denver: Bureau of Land Management, Colorado State Office, 1992), 43-56, accessed March 17, 2017, https://www.blm.gov/style/medialib/blm/wo/Planning_and_Renewable_Resources/coop_agencies/new_documents/co4.Par.36501.File.dat/orourke.pdf . O'Rourke's book serves as the primary reference for the early history of the valley.
[173] Jack Pfertsh, "History and Background of the Hanging Flume," (December 2005), accessed November 29 2015, http://hangingflume.org/wp-content/uploads/2013/12/History-and-Background-of-the-Hanging-Flume.pdf.
[174] The "Hanging Flume" was added to the National Register of Historic Places in 1980, Colorado Preservation, Inc. added the flume to the Endangered Places List in 1999, and in 2006 it was added to the World Monuments Fund Watch List.
[175] Charles L. Parsons, "Our Radium Resources," *Journal of Industrial and Engineering Chemistry* 5:11 (Nov. 1913), 944. The discovery of carnotite has a complex history; see also R. C. Coffin, *Radium, Uranium, and Vanadium Deposits of Southwestern Colorado, Bulletin 16*, (Denver: Colorado Geological Survey,1921), 150-153; Otto Brill, "Uranium in Colorado," *Radium* 1:1 (April 1913), 10-11; Kathleen Bruÿn, *Uranium Country* (Boulder: University of Colorado Press 1955), 29-33; and Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 7.
[176] Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 95; Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 13.
[177] Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 95.
[178] Richard B. Moore and Karl L. Kithil, *A Preliminary Report on Uranium, Radium and Vanadium*, *Bureau of Mines Bulletin 70,* (Washington: Government Printing Office, 1913), 34.
[179] Charles H. Viol, "There is No Radium Shortage," *Radium* 13:1 (April 1919), 7.

[180] Moore and Kithil, *A Preliminary Report on Uranium, Radium and Vanadium, Bureau of Mines Bulletin 70*, 41.
[181] Moore and Kithil, *A Preliminary Report on Uranium, Radium and Vanadium*, *Bureau of Mines Bulletin 70,* 39-40.
[182] Charles H. Viol, "The Commercial Production and Uses of Radium," *Journal of Chemical Education* 3:7 (July 1926), 759.
[183] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 13.
[184] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 14, 17.
[185] Vogt, "Radium – The Wonder Element," 148.
[186] Mullin received his Civil Engineering degree in 1901. He played on the varsity football team and had the distinction of being its only three-time captain, in 1897, 1898, and 1899. Robert C. Balfe, "Notre Dame Football Captains," *The Notre Dame Alumnus,* 9:2 (October 1930): 84, accessed March 28, 2017, http://www.archives.nd.edu/alumnus/vol_0009/vol_0009_issue_0002.pdf. Mullin was profiled by *Sunset* magazine, W.F. Wilcox, "Interesting Westerners," *Sunset The Pacific Monthly* 40:5 (October 1918), 42-43, accessed March 28, 2017, https://books.google.com/books?id=toA3AQAAMAAJ&pg=RA3-PA2&lpg=RA3-PA2&dq=Sunset,+the+Pacific+Monthly+May+1918&source=bl&ots=-fmy8_n83s&sig=BQ-_g3OHgKSqyPc5IYOGDSNE8J8&hl=en&sa=X&ved=0ahUKEwi8k6f9n_nSAhWo1IMKHaagCZsQ6AEIJjAC#v=onepage&q=Sunset%2C%20the%20Pacific%20Monthly%20May%201918&f=false.
[187] Riley, Photo 50, Albert D. Riley Photograph Albums, vol. 1; U.S. Congress, Senate, Committee on Mines and Mining, *Radium: Hearing before the Committee on Mines and Mining on S. 4405*, 31.
[188] Riley, unnumbered photo following 50B, Albert D. Riley Photograph Albums, vol. 1.
[189] Riley, unnumbered photo below 81B, Albert D. Riley Photograph Albums, vol. 1.
[190] Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 96.
[191] Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 96-97; Riley, Photo 43, vol. 1, Albert D. Riley Photograph Albums.
[192] Rimrocker Historical Society, *Standard Chemical Company*, (Naturita: Rimrocker Historical Society, 2007), 36-37, 55-63.
[193] Rimrocker Historical Society, *Standard Chemical Company,* 45; Anon., "Standard Chemical Co. Has Gasoline Tank Car," *Telluride Daily Journal* (October 6, 1922).
[194] Viol, "The Commercial Production and Uses of Radium," 759.
[195] John S. Hamrick, Diane E. Kocis and Sue E. Shepard, *Uravan, Colorado One Hundred Years of History,* (Grand Junction: Umetco Minerals Corporation), 2002," 24.
[196] John A. Hardcastle, "Halfway Between Nobody Knows Where and Somebody's Starting Point," (MA diss., Utah State University, 1998), 37.
[197] Anon., (no headline), Telluride Journal (December 11, 1013).

[198] Rimrocker Historical Society, *Standard Chemical Company*, 14-15.
[199] Riley, photo 97, Albert D. Riley Photograph Albums, vol. 2.
[200] Rimrocker Historical Society, *Standard Chemical Company*, 33.
[201] Riley, Introductory notes, Albert D. Riley Photograph Albums, vol. 1.
[202] Rimrocker Historical Society, *Standard Chemical Company*, 16-28; Hardcastle, "Halfway Between Nobody Knows Where and Somebody's Starting Point,"26.
[203] Rimrocker Historical Society, *Standard Chemical Company,* 49, 67**.**
[204] Rimrocker Historical Society, *Standard Chemical Company,* 10.
[205] Riley, unnumbered set of five photos, last in the album, Albert D. Riley Photograph Albums, vol. 1.
[206] Rimrocker Historical Society, *Standard Chemical Company*, 15.
[207] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 80; 2018 cost calculated using the "Federal Reserve Bank of Minneapolis Consumer Price Index (Estimate) 1800-", accessed January 24, 2019, https://www.minneapolisfed.org/community/financial-and-economic-education/cpi-calculator-information/consumer-price-index-1800.
[208] U.S. Congress, Senate, Committee on Mines and Mining, *Radium: Hearing before the Committee on Mines and Mining on S. 4405*, 40; 2018 cost calculated using the "Federal Reserve Bank of Minneapolis Consumer Price Index (Estimate) 1800-", accessed January 24, 2019, https://www.minneapolisfed.org/community/financial-and-economic-education/cpi-calculator-information/consumer-price-index-1800.
[209] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 62; Charles H. Viol, "The Story of Mme. Curie's Radium," Radium 17:3 (June 1921), 50; "Storehouse of Precious Ore Is In Colorado," *Telluride Daily Journal*, January 28, 1922.
[210] U.S. Congress, Senate, Committee on Mines and Mining, *Radium: Hearing before the Committee on Mines and Mining on S. 4405*, 35.
[211] Boyd Crumrine, ed. *History of Washington County Pennsylvania*, (Philadelphia: L. H. Everts & Co, 1882), 601, 606, accessed December 19, 2016, https://archive.org/details/historyofwashing00crum.
[212] Crumrine, *History of Washington County Pennsylvania*, 396.
[213] James T. Herron, Jr., "Canonsburg's prosperity arrived by railroad," *Jefferson College Times* (March 2000), no pagination or volume and issue number provided, accessed April 1, 2017, http://www.chartiers.com/jeff/2000-Mar/charvrr.html.
[214] Crumrine, *History of Washington County Pennsylvania*, 627
[215] Joel O. Lubenau, "Standard Chemical Company, Marie Curie and Canonsburg," *Jefferson College Times* 38:1 Whole # 143 (March 2005), 8-9.
[216] U.S. Congress, Senate, Committee on Mines and Mining, *Radium: Hearing before the Committee on Mines and Mining on S. 4405*, 40.

[217] Lounsbury, "Famous Pittsburgh Industries," 88. After SCC discontinued production of radium, Vogt moved to New Jersey where he held positions of plant manager and general manager of chemical companies. During World War II, he was a member the War Production Board in Newark, New Jersey, "Louis Fenn Vogt, 71, An Industrial Aid," *The New York Times*, September 2, 1952; Earle R. Forrest, *History of Washington County, Pennsylvania,* (Chicago: S. J. Clarke Publishing Company, 1926), vol. 2, 15-18. Additional biographical information was provided by Peter Vogt, grandson of Louis Vogt, Cabin John, Maryland, by way of telephone conversations and emails with Joel Lubenau in January 2015.
[218] W. F. Bleecker, "Process of Extracting Values from Ores," U.S. Patents 1,065,581 and 1,068,730; Edward R. Landa, "A Historical Review of the Radium-Extraction Industry in the United States (1906-1926) – Its Processes and Waste Products," *Proceedings Fourth Annual Symposium on Uranium Mill Tailings Management*, *(Geotechnical Engineering Program, Civil Engineering Department, Colorado State University)* (Fort Collins: October 26-27, 1981), 3-12.
[219] Viol, "The Commercial Production and Uses of Radium," 759-763.
[220] Viol, "The Commercial Production and Uses of Radium," 761.
[221] Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 97.
[222] Copies of the timetables available courtesy of Edward H. Lybarger, Archivist, Pennsylvania Trolley Museum, Washington PA.
[223] Title 10, Code of Federal Regulations, Part 20 (10 CFR 20), *Standards for Protection Against Radiation, Subpart C-Occupational Dose Limits*, accessed April 1, 2017, https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1201.html.
[224] Vogt, "Radium – "The Wonder Element," 150-151.
[225] Viol. "The Story of Mme. Curie's Gram of Radium," 50.
[226] The locations of the SCC laboratories, offices, and storage vault in the Vanadium Building were deduced from visits to the building by Joel Lubenau and comparison of modern era photographs with photographs in the SCC photo album in the ORAU collection, ORAU Album, Oak Ridge Associated Universities (ORAU) Health Physics Historical Instruments Collection, Oak Ridge, TN, accessed March 1, 1915, http://www.orau.org/ptp/collection/Miscellaneous/photoalbum/photoalbum.htm.
[227] Viol, "The Commercial Production and Uses of Radium," 764.
[228] Viol, "The Commercial Production and Uses of Radium," 765.
[229] Charles H. Viol, "The Story of Madam Curie's Gram of Radium," *Radium* 17:3 (June 1921), 40.
[230] Radium Chemical Company, *Radium – Radium Salts and Applicators* Pittsburgh: Radium Chemical Company (1913), 10-11, (#000144468), Radium Chemical Company Collection, ca. 1913-1925, Medical Trade Ephemera, College of Physicians of Philadelphia Historical Medical Library; U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 62; Viol, "The Story of Mme. Curie's Radium," 71.

[231] Bertram B. Boltwood, "The Life of Radium," *Science,* New Series, 42:1094 (Dec. 17, 1915), 859.
[232] Landa, 'Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 33.
[233] Robert Abbe, "Explosion of a Radium Tube," *Medical Record* 69:16 (Whole No. 1850) (April 21, 1906), 615-616.
[234] Radium carbonate is another non-hygroscopic compound of radium but it was not favored because its physical characteristics made it more difficult to use when making sealed sources, see Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 23.
[235] The Pathé movie, "The rarest substance known – Radium" depicts a close up view of a metal capsule being filled and then capped with a friction fitted plug. Accessed April 1, 2017, http//:www.britishpathe.com. Type "radium" in the internal search engine to access movies about radium.
[236] Radium Chemical Company information brochures, (#000144468), Radium Chemical Company Collection, ca. 1913-1925, Medical Trade Ephemera, College of Physicians of Philadelphia Historical Medical Library.
[237] Anon. (untitled announcement), *Radium* 2:6 (March 1914), unnumbered page following 92.
[238] Charles Hayter, *An Element of Hope, Radium and the Response to Cancer in Canada, 1900-1940* (Montreal: McGill-Queen's University Press, 2005), 27. The compendium was entitled "Compendium of abstracts of papers on the therapeutic use of radium. With a glossary of terms in radioactivity and radiumtherapy." William H. Cameron and Charles H. Viol compiled it although Radium Chemical Company is usually listed as the author as well as publisher. According to WorldCat.org, fourteen libraries have copies, accessed April 4, 2017, https://www.worldcat.org/title/compendium-of-abstracts-of-papers-on-the-therapeutic-use-of-radium/oclc/14734947&referer=brief_results. The Stanford University Lane Medical Library copy has been digitized, accessed April 4, 2017, https://archive.org/details/compendiumabstr00compgoog. The compendium may have served as a model for the Union Minière du Haut Katanga's *Radium Production-General properties-Therapeutic applications-Apparatus*.
[239] "First American Radium - Doctor Brill Brings Precious Bit to This City." *Philadelphia Ledger* (April 2, 1913).
[240] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 63, 66.
[241] Anon., "Notes and Comments," *Radium* 5:1 (May 1915), 24.
[242] Charles H. Viol, "The Radium Situation in America," Radium 4:6 (March 1915): 106.
[243] Cameron joined SCC about 1912 or 1913. In 1929, he left SCC and moved to New York City where he established a medical practice, joined the faculty of the Bellevue Hospital Medical College and, in 1935, was elected president of the American Radium Society. Anon., "Announcements for the Nineteenth Year, 1930-1931, Session Opens September 17, 1930," *New York University Bulletin, University and Bellevue Hospital Medical College,* 30:11 (March 15,

1930), 18, 26, 76; U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 207.
[244] Lounsbury, "Famous Pittsburgh Industries." 110-111; Miller, "Personal Reminiscences of the Early History of the Radium Extraction Industry in the U.S.A.," 92-93.
[245] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 71, 76.
[246] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 41.
[247] Radium Chemical Company, (advertisement), *Radium* 2:4 (June 1914), inside back cover opposite 60.
[248] American Medical Association, annual *New and NonOfficial Remedies* (Chicago: American Medical Association) *1914,* 221-225; *1915,* 262-268; *1916,* 264-272; *1917,* 253-263.
[249] Anon. "The American Radium Society," *Radium* 8:1 (October 1916), 58-59; James T. Case, "The Early History of Radium Therapy and the American Radium Society," *Journal of Roentgenology, Radium Therapy and Nuclear Medicine* 82:4 (October 1959), 582-583; Edith H. Quimby, "The First Fifty Years of the American Radium Society, Inc. 1916-1966," (manuscript), 4-8. The ARS appointed Quimby, an eminent New York radiation physicist and associate member of the ARS, as its historian and asked her to prepare an account of its history for its 50th anniversary in 1966. It consists of fifty pages of type-written text plus four appendixes. ARS displayed it at its annual meeting in 2016 in Philadelphia that celebrated its 100th anniversary. Following the meeting, ARS member Dr. Roger Robison borrowed it for copying and shared a copy with Lubenau (Joel O. Lubenau Collection).
[250] Quimby's account was based upon copies of minutes and programs of ARS meetings that were organized by the ARS secretary and made available to her. Early ARS records were incomplete, e.g. the first two ARS constitutions were missing and reports of committees at presented at early meetings, while noted in the meeting minutes were themselves often missing. Quimby determined from the minutes of the 1916 meeting there were 20 charter members but could only identify 18 of them; Viol was an associate member. The October 1916 Radium article on ARS's creation identified 22 persons present at the organizational meeting. Curiously, 21 are listed as members, including Viol, and a physician is listed as an associate member. The weight of evidence is that there were 22 charter members consisting of 21 physicians (20 American and one Canadian) and Viol as associate member.
[251] Joel O. Lubenau, personal notes (Joel O. Lubenau Collection). ARS member Dr. Roger Robison graciously arranged for Lubenau to attend the ARS 2016 meeting as a guest.
[252] Anon., (Advertisement), *Radium* 1:6 (September 1913), unnumbered page following 14.
[253] Anon., "Notes and Comments'" *Radium* 2:1 (October 1913), 9.
[254] Anon., "Notes and Comments," *Radium* 2:3 (December 1913), 40.
[255] Anon., "Notes and Comments," *Radium* 2:3 (December 1913), 38.
[256] Two films, "Radium" and "The rarest substance known – Radium" have been restored and are available by British Pathé at www.britishpathe.com, accessed April 1, 2017, type "radium" in the internal search engine to access the films.

[257] Curie, *Pierre Curie*, 240-241.
[258] Quimby, "The First Fifty Years of the American Radium Society, Inc. 1916-1966," Appendix III (Joel O. Lubenau Collection).
[259] Maria Rentetzi "The U.S. Radium Industry: Industrial In-House Research and the Commercialization of Science," 437-462.
[260] U.S. Congress, Senate, Committee on Mines and Mining, *Radium: Hearing before the Committee on Mines and Mining on S. 4405*, 63rd Cong., 2nd sess., 91, 176.
[261] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining*, 62; Viol, "The Story of Mme. Curie's Radium," 91.
[262] Robison, "Historia medicinae, Howard Atwood Kelly (1858-1943): founding Professor of Gynecology at Johns Hopkins Hospital & pioneer American radium therapist," 21e-35e.
[263] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,"53.
[264] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,"54; Moore, and Kithil*, A Preliminary Report on Uranium, Radium, and Vanadium, U.S. Bureau of Mines Bulletin 70, Mineral Technology,* 2, 8.
[265] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,"54.
[266] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,"54.
[267] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,"54; Charles L. Parsons, R. B. Moore, S. C. Lind, and O. C. Schaeffer, *Extraction and Recovery of Radium, Uranium, and Vanadium from Carnotite, U.S. Bureau of Mines Bulletin 104*, (Washington: Government Printing Office, 1915), 7-9.
[268] "Bremner Feels Better,"*The New York Times*, December 28, 1913.
[269] $100,000 "Radium Test to Save Bremner's Life," *The New York Times,* December 27, 1913.
[270] "Bremner Feels Better," *The New York Times,* December 28, 1913.
[271] "Bremner is Improving," *The New York Times,* January 13, 1914.
[272] "Vexed; Dr. Kelly Reticent," *The New York Times,* January 11, 1914.
[273] "Vexed; Dr. Kelly Reticent," *The New York Times,* January 11, 1914.
[274] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 9; *The New York Times*, "Control of Radium Urged on Congress," January 20, 1914.
[275] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 226-229.
[276] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 229.
[277] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 235.
[278] *The New York Times,* "U.S. to Conserve Radium Deposits," January 15, 1914; U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 12.

[279] James F. Byrnes (1879-1972), a former district prosecuting attorney, went on to become a U.S. Senator, Supreme Court Justice, and Secretary of State under Harry Truman, see U.S. Department of State, Office of the Historian, *Biographies of the Secretaries of State: James Francis Byrnes*, accessed April 5, 2015, https://history.state.gov/departmenthistory/people/byrnes-james-francis.
[280] American Medical Association, "Queries and Minor Notes, Vanadium as a Therapeutic Agent," *Journal of the American Medical Association* 50:19 (May 9, 1908), 1548-1549.
[281] American Medical Association, "Pharmacology, Vanadium and Its Therapeutic Uses." *Journal of the American Medical Association* 53:4 (July 24, 1909), 309.
[282] American Medical Association, "The Propaganda for Reform, Turner Obesity Cure," *Journal of the American Medical Association* 58:25 (June 22, 1912), 1961-1964.
[283] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 139.
[284] American Medical Association, The Propaganda for Reform, "Proprietary Vanadium Preparations," *Journal of the American Medical Association* 60:3 (January 18, 1913), 225.
[285] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 138.
[286] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 175-197.
[287] Parsons et al., *Extraction and recovery of Radium, Uranium, and Vanadium from Carnotite, U.S. Bureau of Mines Bulletin 104*, 14
[288] G. L. Shumway, *A history of the uranium industry on the Colorado Plateau.* (PhD diss., University of Southern California, 1970), 37; "Rush to Grab Radium Area," *The New York Times*, January 26, 1914.
[289] "Compromise Radium Bill," *The New York Times*, January 29, 1914.
[290] U.S. Congress, House, Committee on Mines and Mining, *Report 214, Radium* 63rd Cong., 2nd sess., 1.
[291] "Bremner Has A Setback," *The New York Times,* February 2, 1914; "Bremner's End Near Gives Up All Hope," *The New York Times*, February 3, 1914; "Mr. Bremner Loses Fight With Death," *The New York Times*, February 6 1914.
[292] "President Sends Sympathy," *The New York Times,* February 6, 1914; U.S. Congress, House, *Robert Gunn Bremner (Late a Representative from New Jersey): Memorial addresses delivered in the House of Representatives and the Senate of the United States,* 63rd Cong., 2nd sess., 1915, accessed May 21, 2017, https://archive.org/details/robertgunnbremne02unit.
[293] U.S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining, United States Senate,* 63rd Cong., 2nd sess., February 10-24, 1914, 27.
[294] U.S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining,* 117.
[295] "Experts Disagree on Treating Cancer," *The New York Times*, March 24, 1914.
[296] U.S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining,* 160-166.

[297] U. S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining,* photo plates following 160.
[298] U.S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining,* 132-133.
[299] U.S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining,* 148.
[300] Charles H. Viol, “There is No Radium Shortage,” Radium 13:1 (October 1919), 8.
[301] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 55; Roger F. Robison, *Mining and Selling Radium and Uranium* (New York: Springer, 2015), 172-173.
[302] Parsons et al., *Extraction and Recovery of Radium, Uranium, and Vanadium from Carnotite, U.S. Bureau of Mines Bulletin 104*, 117.
[303] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 56.
[304] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 56; Viol, “The Radium Situation in America,” 107.
[305] Viol, “The Radium Situation in America,” 117.
[306] Charles L. Parsons, R. B. Moore, S.C. Lind, O. C. Schaeffer, *Extraction and Recovery of Radium, Uranium, and Vanadium from Carnotite, U.S. Bureau of Mines Bulletin 104*, 13.
[307] U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 91.
[308] U.S. Congress, House, Committee on Mines and Mining *Radium, Hearing Before the Committee on Mines and Mining*, 56, 106.
[309] Hewett, “A New Occurrence of Vanadium in Peru,” 385; Moore and Kithil, *A Preliminary Report on Uranium, Radium, and Vanadium,[U.S.] Bureau of Mines Bulletin 70, Mineral Technology 2*, 20.
[310] U.S. Congress, Senate, *Minerals and Metals for War Purposes, Hearings before the Committee on Mines and Mining,* 65th Cong., 2nd sess., May 2, 1918, 398.
[311] U.S. Congress, House, *Radium, Hearing Before the Committee on Mines and Mining*, 56.
[312] Landa, “Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,” 48.
[313] Landa, “Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,” 48-49.
[314] Landa, “Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry,” 48-49.
[315] Lounsbury, "Famous Pittsburgh Industries," 135; Vogt, *Radium — The Wonder Element,* 154.
[316] U.S. Patent Nos. 1,240,054, 1,240,055, and 1,240,056.
[317] U.S. Patent Nos. 1,210,625, 1,210,626, 1,210,627, and 1,247,252.
[318] Mellon Institute, “Agreement for Standard Chemical Company’s Industrial Fellowship #1 (Industrial Fellowship #164),” (October 1 1918), Carnegie Mellon University Archives.
[319] Lounsbury, "Famous Pittsburgh Industries," 135; Standard Alloys Company, *Uranium in Steel*, (Pittsburgh: Standard Alloys Company, 1920).
[320] *Earliest Sale of Radium in America with Subsequent Correspondence*, a scrapbook on radium, 1900s-1950s by Robert Abbe and Truman Abbe, accession no. 2000-004, Manuscript Collection,

Historical Medical Library of the College of Physicians of Philadelphia. The cover of the scrapbook is decorated with abstract representations of the seed growths.

[321] C. Stuart Gager, "Radium Rays and Plant Life Processes, Some Interesting Discoveries" *Scientific American Supplement*, No. 1738 (April 24, 1909), 264-266.

[322] "State's Uranium Ores Make Fine Land Fertilizer," *Denver Reporter* (April 27, 1913).

[323] U.S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining*, 28.

[324] C. G. Hopkins, and W. H. Sachs, "Radium as a Fertilizer," *University of Illinois Agricultural Experiment Station, Bulletin No. 177*, (January 1915), 389-401.

[325] Henry H. Rusby, "Radium A Wonderful Stimulant of Farmers' Crops," *The New York Times,* October 24, 1914.

[326] New York Botanical Garden Mertz Library, Records of the Herbarium (RG4) Henry Hurd Rusby Records (1885-1928), Biographical Note (1999), Mertz Library Archives and Manuscript Collections, http://sciweb.nybg.or/science2/libr/finding_guide/rusbyw.asp.html (accessed July 9, 2014); Sharon E. Kingsland, *The Evolution of American Ecology, 1890-2000*, (Baltimore: Johns Hopkins University Press, 2005), 24-25.

[327] Henry H. Rusby, "The Influence of Radioactive Earth on Plant Growth and Crop Production," *Radium*, 4:4, (January 1915) 68-74, 4:5 (February 1915), 94-104. A footnote to the title indicates the article was a lecture delivered at the New York Botanical Garden on November 14, 1914.

[328] Rusby, "The Influence of Radioactive Earth on Plant Growth and Crop Production," 102-103.

[329] Radium fertilizer advertisements in *Country Life* (March 1915), 113 and (June 1915), 93; *House and Garden* (June 1915), 462; *The Garden Magazine* (April 1915), 175, (July 1915), 278, (November 1915), 56; *The Florists' Review* (March 4 1915), 109, (March 18, 1915), 133, (April 1 1915), 60, (April 13, 1915), 85; and *Good Housekeeping* (July 1915).

[330] "Radium Fertilizer is Manufactured Here," *Canonsburg Notes*, April 16, 1915.

[331] H. H. Rusby, "The Influence of Radioactive Earth on Plant Growth - I," *Scientific American Supplement,* No. 2048 (April 3, 1915), 216-218; C. G. Hopkins and W. H. Sachs, "Radium Fertilizer in Field Tests," *Science* 41:1063 (May 14, 1915), 732-735.

[332] R. R. Ramsey, "Radium Fertilizer," *Science* 42:1076 (August 13, 1915), 219.

[333] Anon. "Editorials, Radium As A Fertilizer," *Journal of the American Medical Association* 65:2 (October 9 1915), 1283-1284.

[334] Anon. "Madame Curie Death Brings Memories Here," *The Daily Notes,* (July 5, 1934); G. A. Anderson, "Canonsburg Once Scene of World's Great Supply of Radium, Street Paved with Discarded Residue," *The (Canonsburg, PA) Daily Notes*, (June 21, 1937), 33.

[335] Lounsbury, "Famous Pittsburgh Industries," 135.

[336] Portions of this chapter were derived from Joel O. Lubenau, "Tired, Tenacious, Triumphant: Marie Curie Visits the United States in 1921," *The Invisible Light*, 36 (December 2012), 19-36.

[337] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 25.

[338] U.S. Congress, Senate, *Radium, Hearing Before the Committee on Mines and Mining* 25; U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 63.

[339] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 22, 25
[340] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 22.
[341] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 44
[342] Mullner, *Deadly Glow,* 91; Claudia Clark, *Radium Girls, Women and Industrial Health Reform, 1910-1935*, (Chapel Hill: University of North Carolina Press, 1997), 99. After opening dial painting studios in Pennsylvania and New York, Radium Dial Company was spun off by SCC and moved to Illinois.
[343] Landa, "Buried Treasure to Buried Waste: The Rise and Fall of the Radium Industry," 22, 25
[344] Elizabeth Williams, *Pittsburgh in World War I: Arsenal of the Allies*, (Charleston: The History Press, 2013), 38.
[345] P. R. Jones, "The first half century of chemistry at Clark University," *Bulletin for the History of Chemistry* 9 (Spring 1991), 15-19, accessed July 1, 2015, http://www.scs.illinois.edu/~mainzv/HIST/bulletin_open_access/bull-index.php.
[346] U.S. Patent No. 1,171,464; Anon. "A Sketch of the Life and Work of Joseph M. Flannery," 105-106.
[347] Williams, *Pittsburgh in World War I: Arsenal of the Allies*, 39.
[348] Anon., "A Sketch of the Life and Work of Joseph M. Flannery," 105-106.
[349] Anon., "A Sketch of the Life and Work of Joseph M. Flannery," 106.
[350] The cause of Joseph Flannery's death was reported by Pittsburgh newspapers as pneumonia, "Well-known Pittsburgh Business Man succumbs to Attack of Pneumonia," *Pittsburgh Sun,* February 19, 1920, and "an illness of several months," "J.M. Flannery, Radium Expert, Dies at Home," *Gazette-Times*, February 19, 1921. James Lounsbury cited overwork as the cause of death, Lounsbury,"Famous Pittsburgh Industries,"135. Lounsbury interviewed the widow of Glenn Kammer; a relative of James Gray; Harry Kraeling and William Ganley, former SCC and RCC managers; Arthur Miller and Albert Riley, former technical workers at SCC; and Alexander Silverman, University of Pittsburgh Professor of Chemistry who mentored Glenn Kammer and Henry Koenig — all having first or close-hand knowledge of Joseph Flannery. In 1935, J. Rogers Flannery, son of James J. Flannery, in his account of his father's and uncle's vanadium business venture, simply said that his uncle Joseph "died suddenly," J. Rogers Flannery, "Vanadium, A Romance of Catholic Enterprise," in *Catholic Builders of the Nation*, Constantine E. McGuire, Ed., (New York: Catholic Book Company, 1935), 193-200. None of these accounts suggested exposure to radium as the cause. Then, in 1937, *Scientific American* published a four-part article by John A. Maloney, "Radium- Nature's Oddest Child," 157:1-4, July-October 1937. In Part 3, Maloney wrote of an accident that occurred when SCC workers showed Flannery a minute amount of radium salts displayed in a watch glass; he allegedly sneezed and inhaled some of the radium. Maloney attributed Flannery's death to this incident — "toppling over dead as he crossed the living room floor in his home." Maloney's description of Joseph Flannery's death does not comport those of the newspapers of the day nor with Lounsbury's account and he furnished no information on the source of this story. Maloney's article is rife with errors, e.g., he listed four SCC workers who allegedly died from radium. Two were given incorrect names, Emil

(sic) Krapf and Alvin (sic) Kammer. Furthermore, Krapf, a SCC pharmacist in charge of medical radium solution products, died in 1915 not from radium, but from pneumonia, B. E. Pritchard, "Proceedings of the Local Branches, Pittsburgh," 649; Anon., "German Pharmacists and Pharmacy," *N.A.R.D.* (National Association of Retail Druggists) 20:17 (May 20, 1915), 340. Yet another erroneous account of Joseph Flannery's death surfaced in 1979 when Ben A. Franklin, writing in "U.S. Testing Workers for Effects of 13 Years Amid Atomic Waste," *The New York Times,* May 9, 1979, stated "radiation sickness" was the cause of Flannery's death and the deaths of two other SCC workers. Franklin provided no other information on Flannery's death and, as with Maloney's story, his account is inconsistent with the newspaper reports published at the time of his death, and by Lounsbury and J. Rogers Flannery.

[351] In addition to obituaries, *The Pittsburgh Leader*, *The Pittsburgh Post*, *The Pittsburgh Sun*, and *The Gazette Times* published editorials lauding his life and accomplishments. The editorials were republished by SCC, Anon., "A Sketch of the Life and Work of Joseph M. Flannery," 107-111.

[352] Anon. "Death Takes Bank Head in Oakland," *The Pittsburgh Dispatch*, March 8, 1920; Anon., "James J. Flannery," *The New York Times,* March 9, 1920.

[353] Flannery, "Vanadium, A Romance of Catholic Enterprise" in *Catholic Builders of the Nation*, 199.

[354] "Gray Selected to Succeed J.M. Flannery," *The Pittsburgh Dispatch*, May 19, 1920.

[355] Fleming, George T. *History of Pittsburgh and Environs,* vol. 4, 96; Anon. "Obituary, James C. Gray," *Radium*, Third Series 1:2 (October 1925): 125-126; U.S. Congress, House, Committee on Mines and Mining, *Radium; Hearing before the Committee on Mines and Mining,* 226

[356] Curie, *Pierre Curie*, 322-324.

[357] Susan Quinn, *Marie Curie, A Life* (New York: Simon & Schuster 1995), 384.

[358] Marie Mattingly Meloney Brown, Introduction, in *Pierre Curie,* 15-16.

[359] Brown, Introduction, in *Pierre Curie*,15-16.

[360] Quinn, *Marie Curie, A Life,* 383

[361] Brown, Introduction, in *Pierre Curie,* 17.

[362] Eve Curie, *Madame Curie*, trans. Vincent Sheean (Garden City: Country Life Press 1937), 325.

[363] Brown, Introduction, in *Pierre Curie,*18-20; for more details, see also Quinn, *Marie Curie, A Life*, 383-390; Curie, *Madame Curie*, 322-324.

[364] Mme. Curie. Finds America a Marvel, *The New York Times*, May 25, 1921.

[365] Ann M. Lewicki, "Maria Sklodowska Curie in America, 1921," *Radiology* 223 (May 2002): 302. A copy of Marie Curie's itinerary is in the Detre Library and Archives of the Senator John Heinz History Center. It was mailed by a representative of the Marie Curie Radium Fund in New York to Dr. William J. Holland, a prominent Pittsburgh scientist and member of the Marie Curie Radium Fund who played a key role in organizing the Pittsburgh segment of Marie Curie's visit. Holland Family Papers 1747-1933 (manuscript), MSS 0168, Box #4, Senator John Heinz History Center Library and Archives.

[366] "Mme. Curie Plans to End All Cancers," *The New York Times,* May 12, 1921; W. R. Seabrook, "Madame Curie, Tho [sic] Seasick. Discusses Radium and Faces Cameras as Vessel Docks," *Denver Post*, May 12, 1921.
[367] "Radium Not a Cure For Every Cancer," *The New York Times*, May 13, 1921. The Carnegie residence is now the Cooper-Hewitt National Design Museum, part of the Smithsonian Institution.
[368] Paul Forman, "Duane, William," *Complete Dictionary of Scientific Biography*, (2008), accessed June 27, 2015, http://www.encyclopedia.com/topic/William_Duane.aspx.
[369] Badash, *Radioactivity in America, Growth and Decay of a Science*, 271.
[370] "Smith College Gives Degree to Mme. Curie." *The New York Times,* May 14, 1921.
[371] "Madam Curie in the Valley," *Holyoke Transcript*, May 14, 1921.
[372] "Mme. Curie Here," *Vassar Miscellany News,* May 18, 1921.
[373] Mould, "Radium History Mosaic," 31.
[374] "Mme. Curie Given Memorial Prize," *New York Telegraph,* May 19, 1921, Wellesley Clippings, Lubenau Collection; "Great Audience Honors Mme. Curie," *New York Evening World,* May 19, 1921. The American Association of University Women was founded in 1881 as a voice for equity and education of women. The AAUW has 170,000 members and supporters, 1,000 local branches, and 800 college and university partners, accessed June 21, 2015, http://www.aauw.org.
[375] "Radium Presented to Mme. Curie," *The New York Times*, May 21, 1921.
[376] William deC. Ravenal, *Report on the Progress and Condition of the United States National Museum for the Year Ending June 30, 1921*, (Washington: Government Printing Office, 1921), 29-30.
[377] "Mme. Curie at Dedication," *The New York Times*, May 22, 1921.
[378] "Mme. Curie Ill; Daughter Here to Take Honors," *(Philadelphia) Evening Public Ledger,* May 23, 1921; Anon., "University Honors Madame Curie," *Weekly Magazine of the University of Pennsylvania* 19:31 (May 27, 1921), 853; "Honors for Mme. Curie Received by Daughter," *The New York Times,* May 24, 1921.
[379] The piezo-electric effect had been discovered by Pierre and Paul-Jacques Curie who found that putting pressure on certain materials created electricity.
[380] Robert D. Hicks, "Bringing Physics to Physicians," *Rittenhouse* 23:1 (June 2009), 46-64. The Pierre Curie piezo-electrometer was contaminated by radium. It was decontaminated and repaired by the late Sydney Porter, a Certified Health Physicist from Philadelphia.
[381] Anon., "Notes and Correspondence, Madame Curie Receives Gram of Radium and Many Honors," *Journal of Industrial and Engineering Chemistry* 13, part 1 (June 1921), 573.
[382] "Mme. Curie's Visit Here on Friday is Reported Cancelled," *The (Canonsburg) Daily Notes*, May 25, 1921); "Visit Depends On Her Health.*" The (Canonsburg) Daily Notes,* May 26, 1921.
[383] "Marie Curie Here," *Sewickly Herald*, May 28, 1921.
[384] "Mme. Curie Again Honored," *The New York Times,* May 27, 1921.

[385] "Pitt Degree Conferred on Mme. Curie," *The Gazette Times,* May 27, 1921. The text of Dr. Holland's speech is preserved at the University of Pittsburgh, Chancellor of the University of Pittsburgh, William Jacob Holland, Administrative Files, Collection Number: UA.2.10.1891-1901, ULS Archives Service Center, University of Pittsburgh Library System, Pittsburgh PA, University of Pittsburgh Collection.

[386] "Mme. Curie Again Honored," *The New York Times*, May 27, 1921.

[387] "Mme. Curie Again Honored," *The New York Times*, May 27, 1921.

[388] "Mme. Marie Curie Inspects Big Radium Factory at Canonsburg," *The Pittsburgh Sun,* May 28, 1921.

[389] Louis Fenn Vogt Papers and Photographs, 1921-1952, MSS 86, Thomas and Katherine Detre Library and Archives, Senator John Heinz History Center.

[390] "Memorial Hospital Greets Mme. Curie," *The New York Times*, May 29, 1921; "Mme. Curie, Worn Out, Gives Up Coast Trip," *New York Tribune,* May 29, 1921.

[391] "Marie Curie to Rest at Grand Canyon," *The New York Times.* June 3, 1921.

[392] "Northwestern Confers Degrees," *The New York Times,* June 16, 1921; Anon. "Gibbs Medal Awarded to Mme. Curie," Anon., *The Chemical Bulletin*, 8:7-8 (July-August 1921), 1.

[393] "Mme. Curie Again Ill," *The New York Times,* June 17, 1921.

[394] "Mme. Curie in Boston," *New York World* (June 19, 1921), Wellesley Clippings, Lubenau Collection).

[395] "Lowell Lauds Mme. Curie," *The New York Times*, June 21 1921.

[396] "Angell Inaugurated at Yale Graduation," *The New York Times,* June 23, 1921.

[397] "Mme. Curie. Finds America a Marvel, *The New York Times,* May 25, 1921.

[398] "Olympic Departs With 2,031 Aboard," *The New York Times,* May 26, 1921.

[399] "Marie Curie Reaches France; Children Bring Her Flowers," *New York Tribune*, July 3, 1921. The cask that contained the radium is displayed at the Musée Curie in Paris.

[400] Lubenau, "Tired, Tenacious, Triumphant: Marie Curie Visits the United States in 1921," 30.

[401] Lubenau, "Tired, Tenacious, Triumphant: Marie Curie Visits the United States in 1921," 29; Françoise Giroud, *Marie Curie: A Life,* Lydia Davis, Trans., (New York, London: Holmes & Meier, 1986): 243.

[402] Calculated using the "Federal Reserve Bank of Minneapolis Consumer Price Index (Estimate) 1800-", accessed January 24, 2019, https://www.minneapolisfed.org/community/financial-and-economic-education/cpi-calculator-information/consumer-price-index-1800.

[403] Mould, *Annotated X-ray Bibliography 1896-1945 also containing some references on nuclear physics, radioactivity, & nuclear medicine,* 24.

[404]Allen Brodsky, Ronald L. Kathren, and Charles A. Willis, "History of the Medical Uses of Radiation: Regulation and Voluntary Standards of Protection," *Health Physics* 69:5 (November 1995): 783-792. This special issue of *Health Physics* commemorated the 100 years of the medical use of radiation. Pages 783-787 of the paper by Brodsky, Kathren and Willis cover the earliest years of the development of radiation protection knowledge, 1896-1940, which include the years of SCC's commercial production of radium, 1913-1921.

[405] Brodsky, Kathren, and Willis, 784.
[406] Brodsky, Kathren, and Willis, 784.
[407] Charles Baskerville, *Radium and Radioactive Substances*, 115; Mould, "Radium History Mosaic," 53-54.
[408] Curie, *Pierre Curie,* 117-118; Baskerville, *Radium and Radioactive Substances,* 116. Baskerville also included a photograph taken of Pierre Curie's arm showing the scar.
[409] Curie, *Pierre Curie,* 118.
[410] Henri Becquerel and Pierre Curie, "Physiological Action of Radium Rays," *Scientific American Supplement*, 52:1354 (December 14, 1901), 21705.
[411] Robert Reid, *Marie Curie,* (New York: Saturday Review Press/E. P. Dutton & Co., 1974), 121.
[412] Reid, *Marie Curie,* 121.
[413] E. R. N. Grigg, *The Trail of the Invisible Light,* (Springfield: Charles C. Thomas, 1965), 383.
[414] "Canonsburg Radium Shipped to Europe," *Canonsburg Notes*, May 22 1913.
[415] Anon., "Radium Extracted in America," *Paint, Oil and Drug Review*, 56:13 (September 24, 1913), 35.
[416] Alexander Silverman, "Pittsburgh's Contribution to Radium Recovery," 303-308.
[417] Anon., "Reviews and Abstracts: F. Gudzent and L. Halberstaedter. Occupational Injuries Due to Radioactive Substances," *Radium*, 3:3 (June 1914), 27-29.
[418] Anon., "Reviews and Abstracts, F. Gudzent and L. Halberstaedter. Occupational Injuries Due to Radioactive Substances," Radium 3:3 (June 1914), 28-29.
[419] Thomas Ordway, "Occupational Injuries Due to Radium," *Radium* 6:6 (March 1916), 121-134. The article was also reprinted in the *Scientific American Supplement* but without the illustrations, see No. 2102 (April 15, 1916), 254-256.
[420] Ordway, "Occupational Injuries Due to Radium," 122.
[421] Ordway, "Occupational Injuries Due to Radium," 132-34.
[422] Charles H. Viol, "A Convenient Forceps for Handling Radium Tubes," *Radium* 6:6 (March 1916**),** 134-136.
[423] Viol, "A Convenient Forceps for handling Radium Tubes," 134. The "past three years" would be 1913 to 1915. In those years, SCC produced 13.6 g of radium.
[424] Viol's figure for the reduction of the exposure is an approximation based upon an assumption that the radium is a point source. In fact, radium in glass tubes are linear sources. The reduction in radiation when moving away from a linear source is not as great. Nonetheless, Viol's point that using forceps to distance the fingers from radium sources greatly reduces exposure and risk remained valid.
[425] Anon., "The Dangers in Working With Radium and X-rays. How the Problem is Being Met," *Radium* 17:4-5 (July-August 1921), 53-60.
[426] Anon., "The Dangers in Working With Radium and X-rays. How the Problem is Being Met," 54-55.

[427] Anon., "The Dangers in Working With Radium and X-rays. How the Problem is Being Met," 56.
[428] The British report was published in the British Medical Journal (June 25, 1921), 936-937; Anon. "The Dangers in Working With Radium and X-rays. How the Problem is Being Met," 56.
[429] Anon. "The Dangers in Working With Radium and X-rays. How the Problem is Being Met," 57-60. The Committee updated its report in December 1923 but with respect to radium and radon protection, the Committee reiterated its 1921 recommendations, see X-ray and Radium Protection Committee, "Revised Report No. 1," *Radium* New Series 3:3 (October 1924), 207-213.
[430] George E. Pfahler, M.D., "The Effects of the X-ray and Radium on the Blood and General Health of Radiologists," *American Journal of Roentgenology* 1110 (October 1922): 647-656; Republished in *Radium* 2, New Series:2 (July 1923), 159-168.
[431] R. C. Williams, "Preliminary Note on Observations Made on Physical Condition of Persons Engaged in Measuring Radium Preparation," *Radium* New Series 3:1 (April 1924): 43-66. Reprinted from *Public Health Reports* 38:51 (December 21, 1923), 3007-3028.
[432] Viol, "A Convenient Forceps for Handling Radium Tubes," 136.
[433] "Prof. Curie Killed in a Paris Street," *The New York Times* (April 20, 1906).
[434] Maria Rentetzi, *Trafficking Materials and Gendered Experimental Practices: Radium Research in Early 20th Century Vienna*, (New York: Columbia University Press Gutenberg-e, 2007), chapter 2, paragraphs 29, 30, accessed June 15, 2015, http://www.gutenberg-e.org/rentetzi/index.html.
[435] Maria Rentetzi, *Trafficking Materials and Gendered Experimental Practices: Radium Research in Early 20th Century Vienna*, chapter 2, paragraph 32.
[436] Anon., "Note and Comments," *Radium*, 1:2 (May 1913), 9.
[437] See the "Balance Room" photo in the ORAU Album and note, in particular, the window which contains mullions (window dividers), a feature absent from the Vanadium Building windows which consisted of large, plain upper and lower glass panes.
[438] Frederick Proescher, "The Intravenous Injection of Soluble Radium Salts, Radium 2:4 (January 1914), 45-46. This was the second of four articles in *Radium* by Proescher on the subject; the others are: "The Intravenous Injection of Soluble Radium Salts in Man," *Radium*, 1:4 (July 1913), 9-10; "The Intravenous Injection of Soluble Radium Salts. II," *Radium* 2:5 (February 1914), 6-64; "The Intravenous Injection of Soluble Radium Salts. III," *Radium*, 2:6 (March 1914), 77-87.
[439] Mullner, *Deadly Glow, The Radium Dial Painter Tragedy*, 66-69.
[440] Clark, *Radium Girls, Women and Industrial Health Reform, 1910-1935*, 12-18, 33-38; Harrison S. Martland, "Radium Poisoning," *Monthly Labor Review* 28:6 (1929), 40-41, accessed April 22, 2017, www.jstor.org/stable/41814411.
[441] M. Szamatolski, "Report: M. Szamatolski, Ph. D., January 30, 1923," in Harrison S. Martland, "Radium Poisoning," *Monthly Labor Review* 28:6 (June 1929), 40-41. In April 1923,

Szamatolski, following receipt and analysis of the luminous paint, confirmed his January 1923 conclusion.

[442] Clark, *Radium Girls, Women and Industrial Health Reform, 1910-1935*, 84, 86.

[443] Frederick L. Hoffman, "Radium (Mesothorium) Necrosis," *Journal of the American Medical Association* 85:13 (September 26, 1925), 961-965; Clark, *Radium Girls, Women and Industrial Health Reform, 1910-1935*, 90, 96-99.

[444] Harrison S. Martland, Philip Conlon and Joseph P. Knef, "Some Unrecognized Dangers in the Use and Handling of Radioactive Substances," *Journal of the American Medical Association* 85:23 (December 5, 1925): 1769-1776.

[445] Martland, Conlon, and Knef, "Some Unrecognized Dangers in the Use and Handling of Radioactive Substances," 1769.

[446] Mullner, *Deadly Glow, The Radium Dial Painter Tragedy*,) 69-108; Clark, *Radium Girls, Women and Industrial Health Reform, 1910-1935*. 102-169. Reportedly, Marie Curie was among those challenging Martland's findings having sent Martland a letter asserting that radium was a cure, not a cause, of cancer, see Brodsky, Kathren, and Willis, "History of the Medical Uses of Radiation: Regulation and Voluntary Standards of Protection," 791.

[447] Anon., "Chapter Grand, Dr. Glenn Donald Kammer '13 (Charter Member of Pennsylvania Iota)," (Obituaries), *The Scroll, Phi Delta Theta,* 52:3 (December 1927), 161-163; Harrison S. Martland, "Radium Poisoning," 60.

[448] Silverman, "Pittsburgh's Contribution to Radium Recovery," 307-308; Anon., "Obituary Glenn Donald Kammer," *The Journal of Industrial and Engineering Chemistry,* 5:23 (December 10, 1927), 9.

[449] Anon., "Alumni," *Duquesne Monthly* 2:7 (April 1914): 281, Martland, "Radium Poisoning," 60.

[450] Martland, "Radium Poisoning," 60.

[451] Anon., "Dr. Charles H. Viol, Radium Expert Dies of Cancer in His 42nd Year," *The New York Times,* April 7, 1928; Silverman, "Pittsburgh's Contribution to Radium Recovery" 307-308, Martland, "Radium Poisoning," 60.

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[453] Lounsbury, "Famous Pittsburgh Industries," 336.

[454] Silverman, "Pittsburgh's Contribution to Radium Recovery," 307-308.

[455] "Pittsburgher Dies, Martyr to Radium Research Work," *Pittsburgh Press*, May 21, 1934; "Radium Chemist Suffers Martyrdom for Science," *Oakland Tribune,* May 22, 1934.

[456] S. Mannella, "Body of Curie aide to be exhumed here," *Pittsburgh Post-Gazette,* June 13, 1986).

[457] "Ex-Councilman in Dormont Dies" *Pittsburgh Press,* March 12, 1963.

[458] "Dormont Expert Risks Life to Move a Dab of Radium" *Pittsburgh Press*, July 2, 1939.

[459] Arthur L. Miller, "Searching Ash Wagon for a Clinker," *Radium* New Series 2:3 (October 1923), 235-240.

[460] "Dormont Expert Risks Life to Move a Dab of Radium," *Pittsburgh Press,* July 2, 1939; "Radium Mover Really Quits Perilous Job, Retires After One Last Fling to Aid a Friend," *Plattsburgh Daily Press,* August 11, 1939.
[461] "Arthur L. Miller" (Obituary), *Rochester News-Sentinel,* March 11, 1963, reprinted in http://www.findagrave.com/cgi-bin/fg.cgi?page=gr&GSln=Miller&GSfn=Arthur&GSmn=L+&GSby=1892&GSbyrel=in&GSdy=1963&GSdyrel=in&GSob=n&GRid=43003927&df=all& (accessed June 16, 2015).
[462] "Puzzling A-tomic [sic] Ache, Eerie 'Glowing Pains' Light On Empty House in Dormont" *Pittsburgh Press,* July 28, 1963.
[463] John A. Maloney, "Radium – Nature's Oddest Child," *Scientific American*, 18-20; 157:2 (August 1937) 84-85. Maloney's article is a source of confusion regarding deaths at SCC. Maloney listed four workers who died from radium, Emil (sic) Krapf, Alvin (sic) Kammer, Paul F. Hague, and Charles H. Viol. Krapf died in 1915 but the cause of death was pneumonia, see Pritchard, B. E. "Proceedings of the Local Branches, Pittsburgh," *Journal of the American Pharmaceutical Association* 4:5 (May 1915), 649; Anon., "German Pharmacists and Pharmacy," *N.A.R.D.* (National Association of Retail Druggists), 340. Koenig's death in 1934 was not noted by Maloney.
[464] Elizabeth Rona, "Laboratory Contamination in the Early Period of Radiation Research," *Health Physics* 37:6 (December 1979), 723-727.
[465] Elizabeth Rona, "Laboratory Contamination in the Early Period of Radiation Research," 723.
[466] Alexander Silverman, "Radioactivity and the University of Pittsburgh," 483-484.
[467] Anon. "Chapter Grand, Dr. Glenn Donald Kammer, Pittsburgh '13 (Charter Member of Pannsylvania Iota" (obituary), *The Scroll Phi Delta Theta* 52:3 (December 1927), 163.
[468] Landa,"Buried Treasure to Buried Waste," 20, 25.
[469] Louis F. Vogt, "Radium and Its Production" (paper presented to the Cleveland Section of the American Chemical Society, October 18, 1921). A dictated copy of the paper typed by his secretary, Mary A. Dickens, was preserved by the late James T. Herron, Canonsburg, PA. A copy is preserved in the Joel O. Lubenau Collection. Vogt stated that SCC had produced 82 grams of radium up to October 18, 1921. Cameron, in his 1922 communication with Dr. George Pfahler about SCC, stated SCC had produced 85 grams, see Pfahler, "The Effects of the X-ray and Radium on the Blood and General Health of Radiologists," 647-656. Since SCC production of radium ended in 1922, Cameron's figure of 85 grams may be taken as the final statement on SCC radium production.
[470] Shumway, "A history of the uranium industry on the Colorado Plateau," 75.
[471] Thomas E. Woods, Jr., "The Forgotten Depression of 1920," *The Intercollegiate* Review (Fall 2009), accessed April 5, 2017, https://mises.org/library/forgotten-depression-1920.
[472] Shumway, *A History of the Uranium Industry on the Colorado Plateau*, 75.
[473] Shumway, *A History of the Uranium Industry on the Colorado Plateau*, 75.
[474] A. Adams, "The Origin and Early Development of the Belgian Radium Industry," *Environment International*, 19 (1993): 491-501.

[475] Lounsbury, “Famous Pittsburgh Industries, 136; H. A. Doerner, “Possibilities of Production of Radium and Vanadium from Carnotite,” *Industrial and Engineering Chemistry,* 22:2 (February 1930): 185.

[476] Adams, “The Origin and Early Development of the Belgian Radium Industry,” 492.

[477] Silverman, “Radioactivity and the University of Pittsburgh, 483.

[478] Shumway, *A History of the Uranium Industry on the Colorado Plateau*, 76-77.

[479] U.S. Geological Survey, “Large Deposits of Radium Ore Discovered in Africa,” *Radium,* New Series 1:1 (April 1923): 308-309.

[480] Presumably SCC and Radium Corporation of Colorado, in order to avoid direct competition with each other, agreed to divide their sales geographically with SCC servicing the eastern part of the U.S., and Radium Company of Colorado the western part.

[481] William Ganley, memorandum dated April 28, 1938, no addressee, annotated “Personal communication from Wm. Ganley, President, Radium Dial (New York City) former officer of Standard Chemical Company,”Joel O. Lubenau Collection. Lounsbury presented an alternative view of the contract terms, indicating that SCC was permitted to continue to operate its mines and other works during the three-year term of the contract although in 1926, as a condition for renewal of the contract, UMHK required SCC to cease production of radium and act solely as its sales agent, see Lounsbury, “Famous Pittsburgh Industries,” 136. However, given a November 19, 1922 press notice from the U.S. Geological Survey that U.S. companies had closed their mines Ganley’s version is the more likely, see U.S. Geological Survey, “Large deposits of Radium Ore Discovered in Africa,” 309.

[482] ‘Canonsburg Radium Plant Is Burned,” *Pittsburgh Times-Gazette*, January 2, 1926; Standard Chemical Plant Dismantled And Is Closed Down, *Canonsburg Daily Notes*, February 9, 1927.

[483] Shumway, *A History of the Uranium Industry on the Colorado Plateau*, 72-73.

[484] Anon., “Obituary James C, Gray,” 125-126. His death came “following a protracted illness.” Lounsbury stated the cause was cancer, see Lounsbury, “Famous Pittsburgh Industries,” 136. After Gray became president of SCC, he carried a glass vial of radium in a vest pocket that “He liked to show to friends and business acquaintances who would marvel with him as he said, ‘Imagine, in this tiny bottle is a substance worth $10,000,” about the equivalent of 100 milligrams. Gray then developed radiation burns on his abdomen that worsened into abdominal cancer, see Helen Knox, “Early Years of Radium Research Leave Grim Wake of Death Here,” *Pittsburgh Sun-Telegraph* (May 8, 1960).

[485] Anon., “Mr. Albert R. Raymer, President, Standard Chemical Company, Pittsburgh, Pa,” *Radium,* Third Series 1:2 (October 1925): 65-66.

[486] As far is known, Joseph A. Kelly and Dr. Howard Kelly of Baltimore were not related.

[487] Lounsbury, “Famous Pittsburgh Industries,” 136, Rice, “Reporter at Large - Ripe,” *New Yorker*, (September 18, 1948), 74.

[488] Michael Amundson, *Yellow Cake Towns,* (Boulder: University Press of Colorado): 5.

[489] David W. Zugschwerdt and Susan D. Gerzoff, “Memorandum to File, In Re. Canonsburg, Pa. Site, DOJ No. 90-9-4-1, Subject: Narrative Summary of facts relevant to liability of former

operators or site owners for clean-up expenses for UMTRCA Remedial Action Site at Canonsburg, Pa., Taken from DOE and NRC Documents," (June 18, 1981), 2, David J. Allard Collection. The year of the sale most often cited is 1929 but other sources differ. For example, Zugschwerdt notes that some documents indicate the sale occurred in 1922 and the U.S. Department of Energy in its Final Environmental Impact Statement on cleanup of the Canonsburg site gives 1933 for the year of the sale, see U.S. Department of Energy, *Final Environmental Impact Statement, Remedial Actions at the Former Vitro Rare Metals Plant Site, Canonsburg, Washington County, Pennsylvania, DOE/EIS-0096-F, Volume*, 1-4.

[490] Division of Corporations. State of Delaware. *The Standard Chemical Company Certificate of Incorporation*, March 5, 1911.

[491] Lounsbury, "Famous Pittsburgh Industries," 136, Rice, "A Reporter at Large – Ripe,"

[492] Rose Marie Pratt, June 30, 2015 email to Joel O. Lubenau, "RE: RCC," Joel O. Lubenau Collection.

[493]New York Department of State, Division of Corporations, "Preliminary Certificate of Consolidation Forming Radium Chemical Company, Inc.," (filed September 10, 1936), Joel O. Lubenau Collection. The officers of the company were Thomas J. Gearing, president and Joseph A. Kelly, secretary. Katherine A. Kelly (presumably Joseph Kelly's wife) was a stockholder. According to the certificate, RCC, Inc. was originally organized in New York in 1933. The 1936 action consolidated the 1933 RCC Inc. with three other companies that had been organized in Delaware, Radium Preparations, Inc. in 1931, Radium Luminous Corporation in 1929, and Radon Company, Inc. in 1930. These actions suggest that Gearing and Kelly began taking steps to transfer corporate control of operations from RCC to the New York RCC Inc. in 1929.

[494] Lounsbury, "Famous Pittsburgh Industries,"136.

[495] "Storehouse of Precious Ore is in Colorado," *Telluride Daily Journal*, January 28, 1922.

[496] "Storehouse of Precious Ore is in Colorado," *Telluride Daily Journal*, January 28, 1922.

[497] "Standard Chemical Company Milling Stored Ore," *Telluride Daily Journal*, April 18, 1922; "Standard Chemical Company Mill Working 3 Shifts," *Telluride Daily Journal*, May 20, 1922; "Standard Chemical Will Lay Off 100 Workers," *Telluride Daily Journal*, October 14, 1922.

[498] "Standard Chemical Co. Working Over Dumps," *Telluride Daily Journal,* April 21, 1923; "Standard Chem. To Start Milling Very Soon," *Telluride Daily Journal*, May 12, 1923.

[499] "Montrose-Great Excitement prevails in all parts of the county over all possibilities," *Fairplay Flume*, April 25, 1924 and *Oak Creek Times*, April 26, 1924; Rimrocker Historical Society, *Standard Chemical Company*, 94-95.

[500] Amundson, *Yellow Cake Towns,* 5-7; "New Modern Town For West Slope," *Steamboat Pilot*, April 3 1936

[501] Amundson, *Yellow Cake Towns,* 20-21, 38-39.

[502] Amundson, *Yellow Cake Towns,* 39-44, 119.

[503] Amundson, *Yellow Cake Towns*,111-112, 120, 142, 160, 163, 176.

[504] Carol Rushin, "Final Close Out Report, Uravan Mill and Adjacent Area, Montrose County, Colorado" (September 29, 2008), not paginated, accessed January 13, 2016, http://www.epa.gov/sites/production/files/documents/FCOR.pdf.
[505]Carol L. Campbell, *Five Year Review Report, Fourth Five Year Review Report for Uravan Uranium Project (Union Carbide Corp.) EPA ID COD007063274, Uravan, Montrose County, Colorado,* prepared for the United States Environmental Protection Agency, Region 8 (September 2010): 5-7, Joel O. Lubenau Collection; Colorado Department of Health, "Uravan Uranium Project," accessed January 13, 2016, https://www.colorado.gov/pacific/cdphe/uravan-uranium-project; Rushin, "Final Close Out Report, Uravan Mill and Adjacent Area, Montrose County, Colorado."
[506] Hamrick, Kocis, Shepard, *Uravan, Colorado One Hundred Years of History*, 50; Rimrocker Historical Society of Western Montrose County, "Uravan Mineral Belt Museum and Tabeguache Campgrounds" (August 2012) not paginated. This is a proposal for a museum facility on the grounds of the former Uravan baseball field that also documents the site's history, Joel O. Lubenau Collection courtesy of the Rimrocker Historical Society.
[507] Carol Rushin, "Final Close Out Report, Uravan Mill and Adjacent Area, Montrose County, Colorado."
[508] Christina Pierce, "Rimrockers triumph After 22 Years Battle for Uravan," *San Miguel Basin Forum* (May 24, 2012); Rushin, "Final Close Out Report, Uravan Mill and Adjacent Area, Montrose County, Colorado."
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[510] U. S. Department of Energy, Office of Legacy Management, "Legacy Management Sites, Naturita Sites," accessed May 13, 2017, http://www.lm.doe.gov/naturita.
[511] The U. S. Department of Energy, is responsible for long-term surveillance and maintenance of the site, for reports see http://energy.gov/sites/prod/files/2014/03/f8/TITLE1.pdf, accessed July 18, 2015.
[512] In January 1980, the *Pittsburgh Press* published six articles on the Canonsburg mill site by Doud Harbrecht and Matthew Kennedy, all headlined "Radioactive Coverup " The articles are "Government Hides Canonsburg Facts," (January 20, 1980), "Problem Buried for Next Generation (January 21, 1980), "Botched Waste Cleanup Haunts 'Hot Graveyard,'" (January 22, 1980), "Town's Dream Turns into Nightmare" (January 23, 1980), "Officials Bury Full Canonsburg Story" (January 24, 1980), "Red Tape Contaminates Plant Cleanup" January 25, 1980). The reporters' articles were based upon numerous interviews and their review of USAEC records obtained through Freedom of Information Act requests. This subchapter is based on their reporting supplemented by other sources as indicated by chapter notes.
[513] David W. Zugschwerdt and Susan D. Gerzoff, "Memorandum to File, In Re. Canonsburg, Pa. Site, DOJ No. 90-9-4-1, Subject: Narrative Summary of facts relevant to liability of former operators or site owners for clean-up expenses for UMTRCA Remedial Action Site at

Canonsburg, Pa., Taken from DOE and NRC Documents," (June 18, 1981) 3, David J. Allard Collection.

[514] First National Bank at Pittsburgh, "The Story of Pittsburgh, Diversified Products, vol. 1, vol. 13 (April 1927).

[515] Amundson, *Yellowcake Towns,* 5.

[516] U.S. Department of Energy, *Final Environmental Impact Statement, Remedial Actions at the Former Vitro Rare Metals Plant Site, Canonsburg, Washington County, Pennsylvania, DOE/EIS-0096-F, Volume 1* (July 1983), 1-4, accessed May 21, 2017, http://energy.gov/sites/prod/files/EIS-0096-FEIS-1983.pdf.

[517] U.S. Department of Energy, *Final Environmental Impact Statement, Remedial Actions at the Former Vitro Rare Metals Plant Site, Canonsburg, Washington County, Pennsylvania, DOE/EIS-0096-F, Volume 1,* 1-8.

[518] Lubenau, while working for the Pennsylvania radiation control program, visited the lagoon area after the burial. The red-dog paving, which indeed had a reddish color, was in poor condition.

[519] James T. Herron, *Canonsburg Reflections, 1802-2002,* (Canonsburg: Canonsburg Bicentennial Commission, 2002, 2003): 68.

[520] The 1946 Atomic Energy Act created the AEC and established civilian control over nuclear energy. The Atomic Energy Act of 1954, as amended, created a licensing system to regulate the use of nuclear materials and established three categories of nuclear materials to be regulated: *source material* for nuclear energy, uranium and thorium; *special nuclear material*, material capable of sustaining a nuclear reaction; and *byproduct material*, the products of nuclear fission. Regulation of these materials was given exclusively to the AEC. Other than uranium and thorium, naturally occurring radioactive materials such as radium and radon, were excluded from the AEC's jurisdiction. In 2005, Congress amended the Atomic Energy Act to extending its authority to radium and other naturally occurring radioactive material.

[521] "Rep. Murphy: 'This Is A First'" *Washington Observer-Reporter* (February 21, 1980).

[522] James G. Yusko, "Canonsburg UMTRA [sic] Site-History and Acquisition," (paper presented at the 1985 Washington Conference on Low level Nuclear Waste Disposal and Clean-up, Arlington Virginia, May 16-17, 1985. Arlington Virginia).

[523] Peter Eisler, "Poisoned Workers & Poisoned Places, Chapter 4: How Clean is Clean Enough," *USA Today* (September 5, 2000), accessed July 10, 2015, http://usatoday30.usatoday.com/news/poison/017.htm.

[524] "Canonsburg Cleanup In Air," *Pittsburgh Press*, September 20, 1981.

[525] Pennsylvania Bureau of Radiation Protection (PaBRP), "Canonsburg/Burrell Disposal Sites; Canonsburg and Blairsville, PA NRC License – General License per 10 CFR 40.72," Joel O. Lubenau Collection.

[526] U. S. Department of Energy Legacy Management, "Canonsburg, Pennsylvania Disposal Site," accessed May 21, 2017, https://www.lm.doe.gov/Canonsburg/Documents.aspx.

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[528] "No Immediate Health Threat," *Pittsburgh Press*, January 25, 1980.
[529] Mark Dickerman and Lamar Sanders, "Video: Fighting Radiation Peril," *Film Library Quarterly*, 14:1 & 2 (double issue) (1981) 40-44; Museum of Modern Art Department of Film Press Release # 27, "Video Documentary Series Continues at MoMA With Six New Works" (April 1983); Anon. "Movies - Museum of Modern Art.…Video Documentaries….“No Immediate Danger" (1982) by Gerald Saldo, Joan Engel," *New York Magazine,* May 30, 1983, all in the David J. Allard Collection. Videocassettes of "No Immediate Danger" are located in Montreal, Quebec at the Concordia Universities Libraries, Cat. No. QC H3G 1M8 Canada and Université de Montréal UdeM, Cat. No. QC H3T 1J4 Canada, see OCLC WorldCat, http://www.worldcat.org/title/no-immediate-danger/oclc/74383566, accessed July 11, 2015.
[530] Anon., "Adolf G. Kammer, M.D. 1903-1962," *Journal of Occupational Medicine* 4:2 (February 1962): 101.
[531] Jan Lieban, "The Radium Trail in Pennsylvania," (paper presented at the Twelfth Annual Health Conference, State College, Pennsylvania), not paginated, 1963, Joel O. Lubenau Collection.
[532] K. J. Mahosky, et al., "Cooperative Decommissioning Between Regulatory and Licensee: A Success Story," (Paper presented at the Waste Management Conference, February 29-March 4, 2004, Tucson, Arizona). The Vanadium/Flannery/Building is the subject of this paper.
[533] Helen Knox, "Radium Contamination in Oakland is Bared," *Pittsburgh Post-Gazette & Sun-Telegraph* May 1, 1960).
[534] The decommissioning of the building is based upon documents originally obtained from the Pennsylvania Bureau of Radiation Protection about 2005: "Final Safety Evaluation Report for the Flannery Building (and) Final Status Survey Report and License Termination, Commonwealth of Pennsylvania, Department of Environmental Protection, Bureau of Radiation Protection, Decommissioning and Environmental Surveillance Division, Radioactive Material License No. PA-0821" (June 2003); "Annual Site Decommissioning Activities Report-2003, Site Identification: Name: Flannery Building (Parkvale Bank), PA License: PA-0821 (terminated)" (2003); K. J. Mahosky, G.E. Williams, N. Y. Best, S. J. Horgan, C. E. DeWitt, Enercon Services, Inc., Murrysville, PA, "Cooperative Decommissioning Between Regulator and Licensee: A Success Story," presented at the Waste Management 2004 Conference, February 29-March 4, 2004, Tucson AZ, *Conference Abstract WM-4070* (2004) , all in the Joel O. Lubenau Collection.
[535] Letter, Ronald J. Hamm, Chief, Radioactive Material Licensing, September 3, 2003 letter to Robert J. McCarthy, Jr., President and CEO, Parkvale Savings Bank, "Re: Pennsylvania Radioactive Material License No. PA-0821," Joel O. Lubenau Collection.
[536] Joel O. Lubenau, "Vanadium - Stained Glass, Helpful Metal," *Western Pennsylvania History* 94 (Winter 2011-12): 55.

[537] Jerry Rosen, email to Joel Lubenau, “RE: Flannery Building” (March 22, 2006). Rosen was the University of Pittsburgh radiation safety officer; this and earlier email exchanges discussed the new occupants of the Flannery Building, Joel O. Lubenau Collection.
[538] “University plans new health and safety building,” *University Times* 38:7 (November 23, 2005): 1.
[539] Michael Sheetz, email message to Joel O. Lubenau, January 17, 2019.
[540] Joel O. Lubenau, “The Vanadium Window,” *Health Physics News* 43:10 (October 2006): 14-15; Joel O. Lubenau, “Vanadium - Stained Glass, Helpful Metal.” 46-59.
[541] “Pittsburgh Stained Glass Studios,” accessed April 9, 2017, http://www.pittsburghstainedglassstudios.com; “Hillman Foundation,” accessed April 9, 2017, http://hillmanfamilyfoundations.org/foundations/hillman-foundation/.
[542] Edith H. Quimby, “The First Fifty Years of the American Radium Society, Inc.,” Archives of the American Radium Society, Los Angeles, California (no date), Appendix III, Joel O. Lubenau Collection, courtesy of Dr. Roger Robison.
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[544] Joel O. Lubenau, “Historia medicinae: The roller coaster price of radium,” *Nowotwory Journal of Oncology* 59:4 (2009): 148e.
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[546] Paul J. Early and Edward R. Landa, “Uses of Therapeutic Radionuclides in Medicine,” *Health Physics* 69:5 (November 1995): 684.
[547] U.S. Department of Health, Education, and Welfare, *Medical Uses of Radium and Radium Substitutes, Public Health Service Publication No. 999-RH-16*, (Washington: U.S. Government Printing Office, 1965), 2; Donald R. Chadwick, “Summary and Conclusions of the Conference on Medical Uses of Radium and Radium Substitutes,” *American Journal of Public Health* 54:11 (November 1966) 1943-1947; Conference of Radiation Control Program Directors, “SCATR Program (Source Collection and Threat Reduction),” accessed April 26, 2017, http://www.crcpd.org/page/SCATR.
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[550] Amy Sisk, “How two Pittsburgh Brothers Launched The First Nuclear Industry,” http://wesa.drupal.publicbroadcasting.net/post/how-two-pittsburgh-brothers-launched-first-nuclear-industry (accessed December 20, 2018).
[551] Joel O. Lubenau, David J. Allard, and Michael A. Sheetz, “Standard Chemical Company - The First US Nuclear Industry,” *Health Physics News* 46:12 (December 2018), http://hps.org/newsandevents/periodic_elements.html (accessed January 16, 2019).

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Photograph collections are listed on pp. 4-5.

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The complete texts of the American Medical Association's *New and Nonofficial Remedies* for the years 1907-1922 are available at the Hathi Trust Digital Library, https://catalog.hathitrust.org/Record/100782317.

American Vanadium Facts, the American Vanadium Company house journal, is available at the Hathi Trust Digital Library, http://catalog.hathitrust.org/Record/011274536. Volume 1, number 1 is missing. The journal was published monthly until 1915, it was not published in 1916, and the apparent last issue, 5:4, was published January 1917. Pagination of the journal began in the January 1913 issue; the cover was page 1.

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VIDEOS

Two Pathé movies, "Radium" and "The rarest substance known – Radium" have been restored by British Pathé. Accessed April 1, 2017, http//:www.britishpathe.com. Type "radium" in the internal search engine to access the movies.

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Edward R. Landa holds an M.S. and Ph.D. in soil science from the University of Minnesota, and was a research project chief at the U.S. Geological Survey (USGS) from 1978 to 2013. After retiring from the USGS he joined the Department of Environmental Science and Technology at the University of Maryland-College Park as an Adjunct Professor. His research has focused on the fate and transport of radionuclides and metals in soil and aquatic environments, and has included studies of radioactive contamination in the Arctic regions, and of the geochemical properties of uranium mill tailings and soils contaminated by radium extraction operations in the early 20th century. He participated in the International Atomic Energy Agency's International Chernobyl Project, and served on the National Academy of Sciences' Committee on Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials. Ed's interest and publication record in the history of science and technology spans from the early 1980's, with a focus on the radium processing industry--a spin-off of his research on the then-recently discovered soil contamination at these sites. This historical research resulted in papers in *Scientific American* (1982) and *Essays in Colorado History* (1987), and a monograph published by the Colorado School of Mines (1987). He has co-authored a series of papers (2003-2014) on the scientific contributions of Lyman Briggs, an American physicist who made major contributions to the Manhattan Project as well as to soil science and botany. Ed has co-edited two books: *Soil and Culture* (Springer, 2010) and *The Soil Underfoot: Infinite possibilities for a finite resource* (CRC Press, 2014).

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