The Invisible Light

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Contents.

Editorial: Keeping Things for a Special Occasion.

The image on the front cover is fun. It's from a bottle of Bergisch sparkling wine that I purchased in 2023 in a lovely shop in Remscheid-Lennep when I attended the ISHRAD meeting held in the German Roentgen Museum. Having returned home there was then the question as to when were we to drink it? And so New Year's Eve seemed a good occasion, and I'm pleased that I managed to soak the label off intact. However the older I get the more I feel that we should just enjoy ourselves and keeping things for a special occasion is more often than not foolish!

The images on the label are from Wuppertal. One is of the Wuppertaler Schwebebahn which is a suspension railway and originally called the German Einschienige Hängebahn System Eugen Langen, named for its inventor Eugen Langen. It is the oldest electric elevated railway in the world and has hanging cars and is a unique system. Also shown is the Müngsten Bridge which crosses the river Wupper, and connects the cities of Remscheid and Solingen., It is the highest railway bridge in Germany at 107 metres. The construction of the bridge started in 1894 and was completed in 1897. The bridge was constructed using advanced techniques of the period, and the architect and engineer was Anton von Rieppel (1852-1926).The bridge was initially called the Kaiser-Wilhelm-Brücke after the Emperor Wilhelm I. When the German monarchy ended after the Great War the bridge was renamed after the nearby town of Müngsten and is now a tourist attraction.

I hope that you enjoy the papers in this issue. Two are based on papers that will be presented a UKIO later this year. Kimberley Bradshaw writes about Florence Stoney, and Edwin Aird on the Million Volt Radiotherapy Unit at St Bartholomew's Hospital. Edwin Aird has a wealth of experience of the history of radiotherapy. I hope to see you in Liverpool.

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How To Kill a Society.
By Adrian Thomas.

I recently acquired a few old copies of the journal *Radiography* from the 1940s and 1950s. *Radiography* was the monthly journal of the Society of Radiographers. There is much of interest in old journals and this one is from February 1952 is of no exception. What caught my eye was a piece 'How To Kill a Society', however in the same month there was a very good paper on the radiographic darkroom by Robert White [1]. White's paper was the winning thesis for the 1951 Archibald Reid Memorial Competition and is an excellent account of the darkroom before any automatic processing and is an invaluably insight into period that is long past.

The paper 'How To Kill a Society' was reprinted from a pre-war *Radiography* (that is pre-1939), and originally appeared in *The X-ray Technician*. The insights are as relevant today as when they were written.

So here they are: 'How To Kill a Society':

1. Don't go to the meetings.
2. If you do, go late.
3. If the weather is bad, don't dream of going.
4. Whenever you do attend a meeting, find fault with the President and officers.
5. Never accept office. It is much easier to sit back and criticise.
6. If you are appointed on a committee, don't go to the meetings; if you are not appointed, get peeved about it.
7. When your opinion is asked in a meeting, reply that you have nothing to say; but after the meeting, tell everyone just how things should be done.
8. Do nothing more than is absolutely necessary; but when others do the lion's share, spread it about that the Society is run by a little clique.
9. Don't think of contributing to the Society's journal; on the contrary, criticise the contributions freely to other members.
10. Don't hurry about paying your subscriptions; wait until you have had several notices.
11. Don't bother about trying to get new members; let those who do the other work do that too.

(If enough members do any of the above things, it will spell the death knell of a Society.)

I could possibly add:

12. Never read any of the circulated papers before a meeting.

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[1] White, R. 1952. The Radiographic Darkroom, Its design and the organisation of its work. *Radiography*, Vol. XVIII, No. 206, 24-29.

Florence Ada Stoney: Formidable Feminism in the History of Radiology.

By Kimberley Bradshaw.

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Introduction:

Historically women have always played an integral role in medicine. However, a gender gap between men and women practicing medicine, has always been evident (Jefferson, Bloor, and Maynard, 2015; Platoni *et al*, 2018). Midwifery is an excellent example of this. Traditionally it was an unregulated profession centred around women, caring for women (Barnawi, Richter and Habib, 2013). Jefferson, Bloor, and Maynard (2015) reflected that after the introduction of obstetric forceps in the 17th century, male practitioners were increasingly tempted into pursuing careers in obstetrics. This was partly because only members of the all-male Barber Surgeon Guild were allowed to practice with surgical instruments (Sheikh, Ganesaratnam and Jan, 2013). This led to a reduction in the traditional female midwifery figures within communities. And so to demonstrate this proposed gender gap; women with years of experience both as practitioners, and quite often having experienced childbirth themselves were frozen out, in favour of male practitioners. This was evidenced by Jefferson, Bloor, and Maynard (2015), who concluded that due to the social status of a medically trained man, it became 'fashionable' to have an obstetrician attend to you in labour, over a female midwife with no formal qualifications.

Despite several of the first Radiological Practitioners being women (Thomas, 2022), Radiology is and historically has been dominated by a male workforce (Hardy, 2017). Gender disparity is an ongoing concern in Radiology (DeBenedictis, 2019). Weigel, Kubik-Huch, and Gebhard (2019) stated that there is a distinct lack of women involved with Radiology Academia, resulting in a lack of female role models for aspiring Radiologists and Radiographers alike. Weigel, Kubik-Huch, and Gebhard (2019) also argued that it is the lack of female role models in Radiology, that negatively affects the career choices of young women in medicine, widening the gender gap that already exists. Although it could be disputed that this is not a worldwide issue, it is commonly recognised that globally, women are underrepresented in medicine, and in particular, Radiology (Cater *et al*, 2018). There are also multiple studies which explore the issue of gender disparity in Radiology across different countries in the World (Lim, Gupta, and Mandel, 2022; Hamidizadeh *et al*, 2018; Zener *et al*, 2015). Grimm *et al* (2017) explored differing motivations for pursuing a career in Radiology according to gender. In their study Grimm *et al* (2017) stated that unfavourable working hours and working conditions both negatively affected women considering Radiology as their chosen career path. Furthermore, a study by Magnavita (2013) explored the mental health of female and male Radiologists. Magnavita (2013) reflected in her findings that female Radiologists suffered greater stress levels than their male counterparts. Although this study was focussed on Radiologists based in Italy, it is important for demonstrating that gender disparity exists within the job role itself, as well as recruitment into said posts.
Despite these common trends, Jefferson, Bloor, and Maynard (2015) and Shannon *et al* (2019) argued in their research that the UK medical workforce was undergoing 'feminisation', with many medical students now being female. This was echoed by Moberly (2018), who produced statistics highlighting the increase in women attending medical school over the last decade. However despite this, as of 2019, only 30% of members of the European Society of Radiology were women (Kubik-Huch *et al*, 2019). Interestingly, a review by Jackson (2022) of 'Invisible Light: The Remarkable Story of Radiology' by Adrian Thomas,

criticised illustrations used for being “stale, pale and male”. Jackson (2022) reflected that a potential reader viewing these illustrations may be mistaken for believing women have not contributed to the success of Radiology or play a part in its future. In a stark contrast, the opposite can be said of practicing Radiographers. According to statistics published by the Health and Care Professions Council, as of 2019, there were 26,059 female Radiographers, compared to 8480 male Radiographers registered in the United Kingdom (HCPC, 2019). Despite this modern-day dilemma, women have played an integral role in the discoveries and developments in Radiology. The lives and achievements of women such as Kitty Clark, Marie Curie and Edith Quimby are all well documented and celebrated (DeBenedictis, 2019). However, the life and career of the less well-known Florence Stoney, is also one to be admired (Thomas, 2003). Even her obituary in the British Medical Journal (Watson Smith, 1932) described the great regret that not more honour was bestowed upon her during her life, given all that she had contributed to her profession**.** Her resilience and determination to fight against the inequalities she faced due to her gender make her an incredible role model, not only for women, but for all embarking on a career in Medicine and Healthcare.

Childhood in Ireland and Education:

Florence Ada Stoney was born into a distinguished family on the 4th of February 1870, in Dublin, Ireland. Florence’s father, George Johnstone Stoney, was a Mathematical Physicist and a Fellow of the Royal Society (Thomas and Duck, 2020). George Stoney was a pioneer within his own field (Duck, 2014). It would be fair to remark that George Stoney was a modern thinking man. Throughout his life, he was an advocate for women’s rights to Higher Education in Ireland. He actively encouraged his daughters to take an interest in education, science, and innovation (Duck, 2014). As Thomas and Duck (2020) reflected in their biography of the Stoney family, this was highly unusual for the era. This was echoed by Kelly (2010) who remarked that a woman studying was deemed a ‘waste’ in the 19th century. Women were not expected to engage with higher education, let alone embark on a career. The consensus was still that a woman would marry, have children, and run a household. Crossman (2017) debated this and highlighted that some women could choose to have a career, but the choices were limited to jobs as nurses, schoolmistresses, or workhouse matrons. It could be argued that there was an increased difficulty to have a career as a middle to upper-class woman, as lower-class women were already contributing to the economy, working within Britain’s ever growing textile trade; thanks to the Industrial Revolution (Braybon, 1981). After The Education Act was introduced in 1870, working class women could work their way into jobs as teachers. Braybon and Summerfield (2012) remarked that this rendered the job ‘dead-end’ and not worthy of someone with class and status, limiting women of higher society even further.

Life in Ireland during the late 19th century was tough. The country was striving for independence and trying to establish its own identity (Graham and Hood, 1998). Female rights were not a priority on the agenda. Conley (1995) described how women were viewed as delicate, and incapable of achieving anything without the supervision of men. Conley (1995) also highlighted that this was a widely accepted opinion during the Victorian Era, and women were expected to be content with a life of submission and obedience. Dyhouse (1998) echoed this in her work, suggesting that women having passions did not reconcile with Victorian and Edwardian ideals. It is certainly no surprise then, considering the chauvinistic attitudes of the era, that women did not dare to pursue their ambitions (Kelly, 2014; Sharma, 2021).

Florence, along with her sister Edith, were privately educated at home, before continuing their education at The Royal College of Science in Dublin. Despite the social reservations at the time, Florence moved to London to study Medicine. This was a necessary move, as women were not permitted to study medicine in Ireland at the time (Thomas and Banerjee, 2013). The London School of Medicine for Women was highly unique, offering medical education to female only intakes (Thomas and Duck, 2020). There were still many arguments about women studying medicine. Kelly (2014) reflected in her research, that the common consensus was that women were not needed in medicine. Kelly (2014) remarked that it was believed an influx of female doctors would cause an unbalance in a male dominated profession, that was already deemed to be successful, without a need for any change. During Florence's time as a student, the dean of the institute was Dr Elizabeth Garrett Anderson- the first woman in Britain to obtain legal qualifications in medicine and surgery (Thomas and Banerjee, 2013). Thomas and Banerjee (2013) reflected that this would no doubt have been inspirational to Florence, and highlighted to her what she could achieve in her own career. During her time as a student Florence excelled, won many prizes, and eventually qualified at the top of her class (Sharma, 2021).

Florence was successful in obtaining her Bachelor of Medicine and Surgery with Honours degree from the London School of Medicine for Women in 1895, just as Wilhelm Roentgen made his remarkable discovery of X-rays (Thomas and Banerjee, 2013). Unbeknown to all, it would be the start of a new age of discovery in medicine. In 1897, 'The X-ray Society' was founded, with an aim of bringing together all those who were interested in the study of 'Roentgen Rays' (Thomas, 2022). This new society would later amalgamate with the British Association of the Advancement of Radiology and Physiotherapy (BARP) to form the British Institute of Radiology in 1924 (BIR, 2023).

Early Career and Exposure to Radiology:

During her studies, Florence excelled at anatomy (Sharma, 2021). After qualifying, she had several small posts, including a House Surgeon position in Hull, and as an Assistant Anaesthetist at the Royal Free Hospital (Guy, 2013). However she returned to her roots in 1899 and took up post as an anatomy demonstrator at the London School of Medicine for Women, following in the footsteps of the women who had inspired her during her own studies. Florence had a keen interest in female health and used her role as a demonstrator to further her knowledge and understanding of female anatomy and pathology (Thomas and Duck 2020). However Florence would yet again face impossibilities due to her gender. Florence aspired to join the academic team, and further her career as an anatomist. However, her application was denied, as women were not permitted to formally teach medicine at the institute (Sharma, 2021). This was surprising given the uniqueness of the institute, and the female driving forces, to which its success could mostly be credited (Guy, 2013).

In 1901, Florence was appointed to the post of Medical Electrician at the Royal Free Hospital. Guy (2002) summarised that clinicians working in early Radiology services were known as Medical Electrician, Medical Photographer, or Honorary Medical Radiographer. It was not until the 1920s, that the role of the Radiographer as we know it to be today, really took shape, and the clinicians involved in imaging adopted their new title of Radiologist (Guy, 2002). Florence worked alongside her sister Edith to establish the X-Ray department. Edith was, by this time, working as a physics lecturer, and had helped introduce physics into the curriculum for medical students (Roth, 2023). Alongside their active parts in the Women's Movement, Florence and Edith selected, purchased, and installed X-Ray equipment into the department (Duck, 2014). As reflected by Thomas (2022), acquiring equipment, and setting up an X-ray department was straightforward, and by the Easter that followed, the new service was up and running (Roth, 2023). Using the equipment to obtain diagnostic images was less straightforward however, and practitioners required skills in photography and electricity with a sound knowledge of anatomy (Thomas, 2022).

Florence eventually moved on to become the head of the Electrical Department at the New Hospital for Women (Duck, 2014). She also set up her own private practice in the prestigious Harley Street. Duck (2014) reflected that it was during this time that Florence continued to develop her skills in Radiology, and Electrotherapy, and began to use X-rays to treat conditions such as uterine fibroids - combining her passion for medical imaging, and female health.

In 1914, just before the outbreak of the First World War, Florence travelled to America to observe how Radiology services were developing abroad (Duck, 2014). Florence later commented at how refreshing her travels to America were. She found the medical staff extremely helpful and commented “I found the doctors in America, both in the hospitals and in private, very ready to allow me to see the work in their departments- medical women not being kept out of everything so much as in England” (BIR, 2023). Florence returned from America, bringing with her a new Coolidge tube. This type of X-ray tube was much more powerful than any used previously, but was easier to regulate (Guy, 2013). So much so, that all modern X-ray tubes are variants of this design (Thomas, 2022). As Duck (2014) summarised, Florence was the first clinician to begin using this new and advanced equipment in England, once again becoming a forerunner in pioneering new ideas in British medicine.

Women at War:

On the 28th of July 1914, hostilities in Europe led to the outbreak of war. The war quickly resulted in high levels of unemployment. For the first time in history, the position of women in society was considered detrimental for ensuring the upkeep of the economy, and in turn, achieving success on the battlefield (Braybon, 1981). At the time, there were insufficient numbers of military hospitals to meet with the demands of the conflict. The armed forces became reliant upon voluntary hospitals (Guy, 2013). Despite the early insufficiencies, the British military medical provision was strong, with over 82 percent of injured soldiers returned to the front line after an initial injury (Carden-Coyne, 2014). The war was an opportune moment for women to strengthen their independence and further their fight for more rights. As stated by Leneman (1994), it was an opportunity for women to prove themselves in a man’s world. By the close of the Great War around one-fifth of female doctors in Britain had undertaken medical work both at home and abroad, during the conflict (Crawford, 2006).

Britain declared war on Germany, on the 4th of August 1914. Guy (2002) surmised that the war resulted in medical developments being brought to a pause in England. However, it could also be argued that the war allowed female practitioners to further their knowledge and earn accolades amongst their male counterparts. The War Office advertised for ‘Military Radiographers’ to assist in the conflict. Duck (2020) reflected that the advertised salary was £200 per annum, highlighting the skill required to fulfil such a role. At the outbreak of the war, Florence already had 13 years’ experience in Radiology (Thomas and Duck, 2019). The very day the war with Germany was declared, Florence, along with her sister Edith, presented at the War Office in London, to volunteer their services to the British Red Cross.

The sisters were keen to provide a Radiology service to aid troops fighting in Europe (Duck, 2014). Once again, misogyny would prevail. Even at a time of great need, Florence and Edith's offer was rejected, purely because of their gender. Moore (2022) described how women were told to 'go home, and sit still' in the face of war, rather than volunteering to help. This was echoed by Thomas (2022), who reflected that the War Office felt they needed to protect women from the horrors unfolding in Europe. Moore (2022) also reflected that despite women having the exact same medical qualifications as their male colleagues, they were not viewed as equals. It was still classed as taboo for a woman to treat a male patient, highlighting the consensus that women were inferior to men. Thomas (2022) also debated this, stating that there was almost a fear about women gaining equality with men, which could be true for any aspect of society at the time, including Politics and the Law.

However, the conflict of the Great War created an environment in which Florence's knowledge and skills became widely needed (Thomas and Duck, 2013), and as reflected by Castelow (2015), ideals about who could participate in the war effort soon changed. Leneman (1994) reflected that suddenly the consensus changed, and women were actively encouraged to train in medicine to assist with the war effort. Pressure from women for their own recognised uniformed service to join the war effort began shortly after its commencement (IWM, 2023). This was also echoed by Shipton (2023), who reflected that a small but significant number of women, rebelled against gender division to actively seek prominent roles within the Armed Forces. By the end of the war, over 200,000 women were in uniformed roles, serving their country (Gritkis, 2013). Interestingly, to highlight the lack of recognition given to these women, Braybon (1981) described how social propaganda in 1918 painted a picture of great appreciation for women at the time, and yet the truth was very different. Braybon (1981) reflected in her research that after the war, the opinion of the surviving male population regarding women, remained the same as it had been before the war. Shipton (2023) also summarised that despite the statistics, many historical accounts still only focus on women in the role of a nurse or working in administration as part of the war effort- not fighting in battle on the frontline.

Despite the rejection, Florence was undeterred. Shipton (2023) reflected that female doctors began to form their own field hospitals and ran them on a voluntary basis. Florence went on to become the Medical Lead at a unit founded by the Women's Imperial Service (Duck, 2014). This fully female team established a 100-bed field hospital in Antwerp. In her own pieces of reflective writing in 1915, Florence remarked on the tough environment she found herself working in during the war. Her team was made up of six female doctors, ten nurses, and several female orderlies. After just two weeks in Antwerp, the team had dealt with over 200 cases of injured soldiers, mostly brought directly from the trenches. Florence described the harrowing scenes, and conditions; including spending eighteen hours under shell fire and trying to run the field hospital with no water and very limited supplies (Stoney, 1915). Duck (2014) reflected that Florence demonstrated amazing clinical skills and expertise in extremely dangerous circumstances throughout her war career.

As the Germans advanced Florence and her team were forced to leave Antwerp (Duck, 2014). Florence would later describe the road out of Antwerp as "a sad procession of fleeing peasants, troops, cattle, guns, wagons, children, and carts, all moving in the same direction as rapidly as possible" (Thomas and Banerjee, 2013). The bridge used to escape Antwerp was bombed, a mere twenty minutes after Florence had fled (Thomas and Banerjee, 2013). The group were then invited to set up base in Cherbourg by the British Red Cross (Thomas and Banerjee, 2013), the very organisation who had earlier rejected Florence and Edith's offer of

their skill and expertise. It is this very expertise, as well as the bravery demonstrated by Florence that make her stand out as a pioneer of her time (Duck, 2014).
In Cherbourg, Florence was named 'Radiographer and Head of Staff', working hard to transform a disused chateau, into a modern military hospital (Thomas and Banerjee, 2013). There were many difficulties for the team to overcome. In the diary of Doctor and Surgeon Mabel Ramsay, (who worked alongside Florence) she described the following issues encountered by the team in Cherbourg:

> *"1. Only one tap of water in the kitchen to supply 150 people.*
> *2. All drinking water had to be fetched by hand.*
> *3. Sanitation very primitive and earth closets had to be built.*
> *4. The turbine engine for electric lighting was out of order and had to be made to work."* (Ramsay, 1920).

Florence returned to London in 1915 (Duck, 2014). London was dominated by the conflict, with much of the war effort being organised within the Capital (White, 2014). Florence was one of the first women in Britain to be recruited by the War Office and was appointed as Head of Radiology at Fulham Military Hospital (Duck 2014). The hospital had a 1000 bed capacity and was busy in its efforts to treat the wounded and return them to the battlefield. Florence's extensive anatomical knowledge and clinical experience proved useful for surgeons with the localisation of bullets and shrapnel within wounds (Thomas, 2003). Thomas (2003) also summarised that Florence was able to identify bony sequestrum, which helped aid the treatment of many wounded soldiers, saving many lives. Florence later credited her time as an anatomy demonstrator with being a great help in her success as a Radiologist (Thomas, 2022). Florence was awarded an OBE in 1919 for her service to the country during the war (Sharma, 2021). She also earned many accolades for her military service, and was awarded the 1914 Star, the British War Medal, the Victory Medal, and the British Red Cross Medal (Thomas and Banerjee, 2013).

Rebuild and Recover: Life After the Great War

The war was declared over on the 11th of November 1918, and the rocky transition back to normality post war for Britain began (Beaumont, 2021). Life for women after the war would be very different, for many reasons (Braybon, 1981). Many women found themselves widowed, or even childless- with generations of families wiped out during the bloodiest conflict seen for centuries (Braybon, 1981). Male security was considered a main priority in the rebuilding of the country, but as Braybon (1981) reflected, it quickly became evident that the role women had carved out for themselves during the war would need to remain, if the country was ever going to rebuild and recover.

There are differing opinions on how the war shaped the future for women in Britain. Braybon (1981) surmised that although some literature reflects on how the war pushed forward the women's rights movement in Britain, other literature argues the war resulted in a watershed in women's history. It could be argued that both points apply, and that whilst women's rights increased significantly after the war, the cause was not for women themselves, but rather a concern for the economic growth of a battered Britain. This was also debated by Leneman (1994) who reflected that it took another war to break out, before medical women gained commissioned rank in the British Army.

After the war Florence was awarded the Radiological Examination Diploma, which had recently been created, as well an Honorary Degree from the University of Cambridge (Thomas and Banerjee, 2013). This was a feat, considering Florence's earlier struggles to access Higher Education. She continued to help develop Radiology as a profession and founded and presided over the Wessex branch of the British Association for the Advancement of Radiology and Physiotherapy (Sharma, 2021). However, Florence's health was failing (Thomas, 2003). As reflected by Matthews and Sexton (2015), the dedication of refining the new technology in Radiology, came at a great personal cost to the professionals involved. Florence herself, personally knew many of the pioneers of Radiology, and knew that the risks of the profession would no doubt catch up with her eventually (Thomas, 2022). Florence developed dermatitis on her hands, a direct result of exposure to radiation during her career. Florence moved to Bournemouth, and continued to practice privately, before retiring in 1928 (Sharma, 2021). Whilst her health allowed, Florence enjoyed travelling with her sister Edith, continuing her learning and research whilst abroad. Her last academic paper was written during a trip to India, where she researched osteomalacia and the link with vitamin D deficiency (Thomas and Banerjee, 2013).

Florence's final years were plagued with cancer. Watson Smith (1932) later reflected in Florence's obituary, that Florence suffered 'greatly and bravely', but did not let her fate deter her from her work. Florence passed away prematurely in 1932, at the age of 62 (Sharma, 2021). Although her death was described as premature, Thomas (2022) reflected that Florence only managed to live with the effects of over exposure to radiation for so long, due to the care she took when using radiation. It was decided that there was not enough evidence to suggest Florence's death had resulted from exposure to radiation, meaning her name was not included on the Martyr's Memorial in Hamburg (Thomas, 2022).

Florence's Lasting Legacy and the Future of Radiology

After Florence's death, Edith set up the Johnstone and Florence Stoney Studentship Fund. The charity aims to support women carrying out scientific research in Australia, South Africa, or New Zealand (Charity Commission for England and Wales, 2023). Thomas and Banerjee (2013) reflected in their account of Florence's life, that Florence had a firm belief in the capabilities of women, and their ability to fill positions of the highest responsibility. Thomas and Banerjee (2013) credited Florence for her courage, iron will, and determination to pass on all her knowledge to the next generation of strong, like-minded women- whether that be through medical education, or the fight for women's rights through movements such as the Suffragettes. Edith herself, died in 1938, leaving behind her own legacy.

In modern healthcare, Radiology is a vital element in both the diagnosis and treatment of patients (GIRFT, 2023). Since 1970, developments in Radiology have transformed it beyond anything previously imagined (Thomas, 2022). There were 43.3 million imaging examinations conducted in NHS settings in England, between April 2021 and March 2022 (NHS Improvement, 2022). Radiology continues to be a popular speciality for medical students. A report for the Royal College of Radiologists by Garrett, Booth, and Kosmin (2016) found that the ratio of Radiology applicants to available study places was consistently at an average of 4:1. This is interesting, given Thomas (2022) reports that satisfaction levels are low amongst Radiologists, and that this has only worsened post pandemic.
There are 44 Medical Schools in the United Kingdom (MSC, 2018) and on average 9500 places to study Medicine at the start of every academic intake (MSC, 2021). There is currently a push to increase the number of places to study Medicine in the United Kingdom

(Lewis and Lewis, 2023). The British Government published their NHS Workforce Plan in June 2023, and have pledged to increase capacity. As part of this commitment, the University of Cumbria have recently announced plans to open the first ever Northern based Medical School, based in Carlisle, in partnership with Imperial College London, in 2025. (Hicking, 2023).

Many advancements have been made since Florence's days as the first female Radiologist in England, not least the formation of the National Health Service in 1948. The role of the Radiographer as we know it today has developed and advanced into a profession of its own, separate to the role of Radiologists. On the 6th of August 1920, the Society of Radiographers was founded, which led to the development of a syllabus, and advancements in the education of Radiographers (Price, 2020). Schools of Radiography were developed, and in 1989, the move into degree level education for Radiographers began (Price, 2009). Since 2003, Radiographers have been regulated by the Health and Care Professions Council (Price, 2020), and the scope of practice for Radiographers has continued to develop and expand. As of 2019, around 11.9% of registered Radiographers in the United Kingdom have roles within advanced practice (SoR, 2019).

The role of the Radiographer is also supplemented by other professional roles, such as Assistant Practitioners, and more recently, Apprentice Radiographers (Sevens, Nightingale, and Ali, 2022). Thanks to the development of these new roles, the routes into Radiography have expanded, which will ultimately help to grow and maintain the Medical Imaging workforce (SoR, 2019, Sevens, Nightingale, and Ali, 2022).

And whilst gender remains a hot topic in modern day Britain, women have elevated their status in society through the pursuit of education, bravery, and iron will- all characteristics demonstrated by Florence Stoney in her remarkable life and career. Both female Radiologists and Radiographers alike, will forever be in her debt. For it is thanks to the platform which she created, that women earned their right to contribute to Radiology, and to uphold careers in one of the most important fields in medicine and healthcare.

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Röntgen Museum Cinderella Stamp.

The Million Volt Radiotherapy Unit at St Bartholomew's Hospital.

By Edwin Aird and Adrian Thomas

Introduction 1: The need for voltages higher than 200kV.
In the early days of deep-seated cancer treatment with x-rays (1920-1930) the maximum kV that could easily be achieved was 200-300KV (although a few units in academic departments had 400kV units).
The typical characteristics of a 250kV x-ray set (Aird E article in The Invisible Light, 2023) were: HVL 3-3.5mmCu giving 30-50R/min at 50cm ; and a depth dose of FSD (depending on filtration; and a depth dose at 10cm of only 32-35%). The difficulty for the radiotherapist wanting to treat tumours at depth, particularly abdominal tumours (typical dimensions: AP 20-25cm; Lat 30-40cm) was to attain adequate dose at the target without irradiating the surrounding tissues (particularly skin)/organs. Several fields from different directions were needed to achieve adequate dose at the tumour, and the skin dose could still be a limiting factor to avoid serious erythema (see below).

The Ideal Energy (of x-rays from an x-ray tube) for deep-seated cancer.
1. Sufficient depth dose at 10cm depth at least 50%.
2. Sufficient scatter to add to primary.
3. But not too much that scatter outside geometric edge of beam giving unwanted dose.
4. Some skin sparing.
5. Bone sparing.

From the experience of USA and NKI (Netherlands) –see below- several important facts emerge:

1. Voltages under 1000kV do not give adequate depth dose compared with 200kV.
2. Skin sparing appears to only happen above 1000kV.
3. Bone sparing becomes significant at 1000kV.

Introduction 2:
By 1933 a few experimental high-voltage x-ray equipment had been constructed in the USA, operating at voltages up to one million, but they were too unreliable in operation to give biological and clinical results which could be assessed.
A few examples of High Energy X-ray Attempts (from "the race for megavoltage x-rays versus telegamma. Roger F Robison Acta Oncologica 1995; 34:1055-1074) and Schulz 1974

1) C.C. Lauritsen tubes from Cal. Tech, 30 ft long using G E transformers in series.

- 600 KV tube at the High Tension Lab. Used by Dr. A. Soiland from Los Angeles from Oct. 1930-Sept. 1932
- 600 KV tube for Dr. Soiland for the Los Angeles Tumor Institute
- 750 KV tube for the Kellogg Lab at Cal. Tech. Used by Dr. S.G. Mudd Sept. 1932-1937

(2) Lauritsen tubes made/sold commercially by Kelley-Koett 1931: 600 KV for Harper Hospital in Detroit

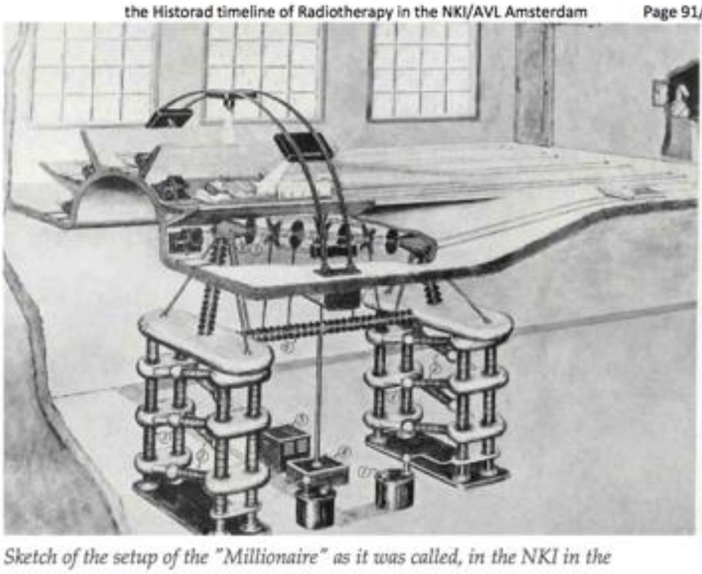
- 1933: 650 KV for Lincoln General, Nebraska
- 1936: 600 KV for Miller Hosp., St. Paul. Minn.

It is worthwhile looking at John Read's experience (J Read 1936) at Cal Tech in 1932-1934 with the Kellogg's set:
The 1000kV tube of the Kellogg Radiation Laboratory , Ca Inst of Tech Pasadena, constructed in 1932 .
Powered from twin transformers (each capable of 1000kV) Read writes of this complicated story: "After weeks of (tube) conditioning it was ultimately possible to operate at a potential as high as 1100 kV" . The tube was in an earthed steel cylinder. It was surrounded by 2" of lead in the centre. Four apertures in the lead 90 deg apart provided 2 horizontal beams and 2 at about 15deg below the horizontal.
Control: galvanometer light spots: 1) Pirani vacuum gauge; 2) the current in the ion chamber in one of the apertures.
The tube voltage calibration obtained with the aid of a spark gap .

The tube was operated and maintained by post-graduate physics research students. During 1932-1934 (Read's period) the tube worked from 9am until 1 pm for treatments; and the reminder of the day for physics research. 6 days a week. About once a month the filament needed changing.
At a tube current of 3mA the dose rate was 15R/min at 60cm FSD(A heavy filtration 5mm steel 1mm lead was used.)
An example of a treatment: 8 fields to pelvis 300R daily over 8 weeks.
3 patients could be treated simultaneously. By using 3 portals from the x-ray target
Over 3-4 years this unit was use 11,000 individual treatments a year (approximately:1200 patents?)

A megavoltage unit at NKI (Amsterdam)
(The historical time line of Radiotherapy at the Netherlands Cancer Institue –Antoni van Leeuwenhoek)
A second unit worthy of further description is the one installed at NKI in Amsterdam.

the Historad timeline of Radiotherapy in the NKI/AVL Amsterdam Page 91/98



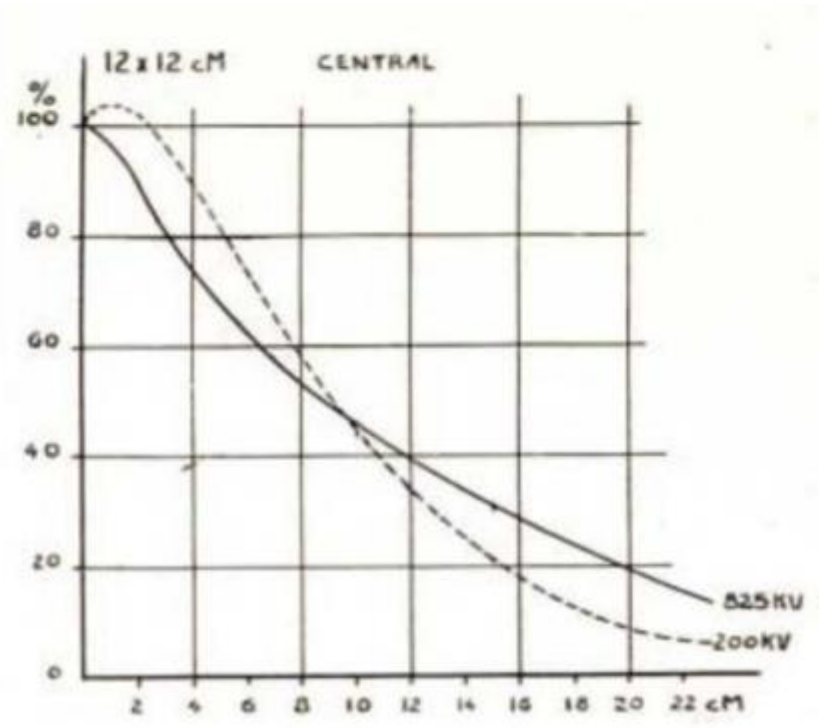
Sketch of the setup of the "Millionaire" as it was called, in the NKI in the Sarphatistraat. Photo Philips Technisch Tijdschrift.

In the cellar stand two cascade rectifiers each of around 600 kV. They are connected to an X-ray tube which is installed up at the ceiling. The machine produced beams in three directions simultaneously through openings in the floor above, so that several patients could be treated at the same time. The positioning of the beams coming up through the floor was particularly difficult and inaccurate.
However, the full potential was not achieved, only 825kV was possible. With kV X-rays of this energy it was found that the radiation dose at depth is not much higher than with the 200 kV radiation which was already available. Also, here is no skin sparing with 825 kV. And due to the low beam intensity of 20 r/min, the radiation treatments take a long time.

1MV vs lower energy x-rays.
These attempts were in good faith; but what wasn't fully understood: the depth dose is a complicated function of : primary beam; forward scatter, and back scatter; and below 1000kV there appears to be little advantage in attempting to work with 600-875kV (NKI) , with the added complications of the electronics and insulation etc, compared with 250kV (as NKI discovered)

The NKI experience with its 875kV energy demonstrates the issues of problems with high energy x-rays that don't quite reach the critical 1000kV point.

Depth Dose:
There is a critical balance above 700kV when side scatter is lower than 200kV-300kV, but the penetrating power (the primary beam HVL), is not sufficient to produce a useful depth dose . This can be seen when the depth doses are compared on a graph. (NKI)



Skin Dose.
The NKI team noticed there was no skin sparing. George Innes (in his Brit Medical Bulletin 1946 paper) noted under the subheading "Alteration in Skin Reaction: Tests were carried out on corresponding skin surfaces on patients with x-ray beams of identical dimensions under the same physical conditions except for the beam qualities. The control beam was one of 300kV, while the experimental beam was 1000kV (HVL 10mm Cu). The dose required in one sitting to produce the same skin reaction was 50% greater with the 1000kV than with the 300kV". This is an extraordinary statement given the lack of knowledge at that time; but demonstrates the skin sparing of the megavoltage beam .
The term "build-up" wasn't used at that time. It is due to the forward emission of the Compton electrons. The approximate 1mm build-up achieved with the Barts 1MV set (see below) appears to be sufficient to reduce the does to the epidermis and to some extent the dermis, markedly reducing skin reaction.

Using existing knowledge of all build-up depths (including Cs-137 and Co-60) we have arrived at an estimate of a build-up depth for the Barts 1MV unit of 0.8mm, but Mayneord (below) gives a higher value. The slope of the build-up curve is fast to begin with; then, from 95% to 100% a very slow increase. For purposes of understanding erythema dose the 1mm figure makes more sense.

Mayneord 1950 (see FT Farmer paper 1962):

Table 1. Variation of depth of build-up peak in water with x-ray generating voltage. (Mayneord 1950.)

X-ray generating Voltage (MeV).	Depth of maximum dose in water (cm)
1	0·25
2	0·5
3	0·7
4	1·0
6	1·4
10	2·6
15	3·5
24	5·0
31	6·0
35	6·3

Bone sparing.
A very nice graph by Dr Frank Farmer (ref 1962) (shown below) demonstrates the lowering of does to bone as the photon energy is increased**.**

Supervoltage Therapy 509

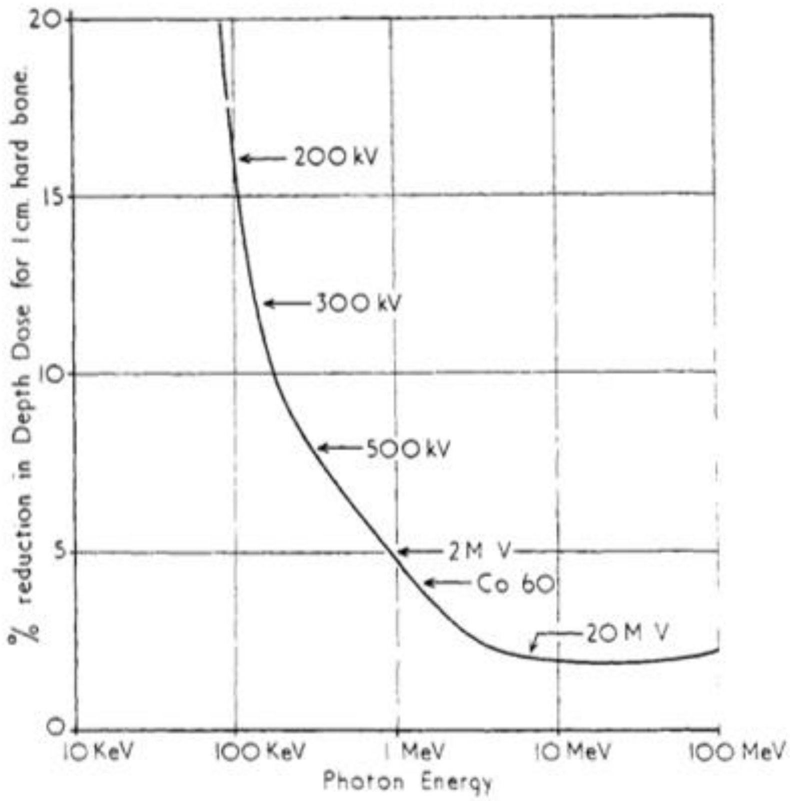


Fig. 2. Shadow of 1 cm of hard bone for a range of photon energies up to 100 MeV. (*By courtesy of W. J. Meredith.*)

The Bart's 1MV Unit.

St. Bartholomew's Hospital, London, contracts with Metropolitan Vickers for a high voltage therapy unit powered by Cockcroft-Walton cascaded generators .

In Dec 1943 the Central Research Committee decides to acquire and attempt to operate an x-ray set for radiotherapy at 1MV to be placed in a building at the east end of great Hall 75-40ft), already occupied by 2 temporary operating theatres (for 20 years).

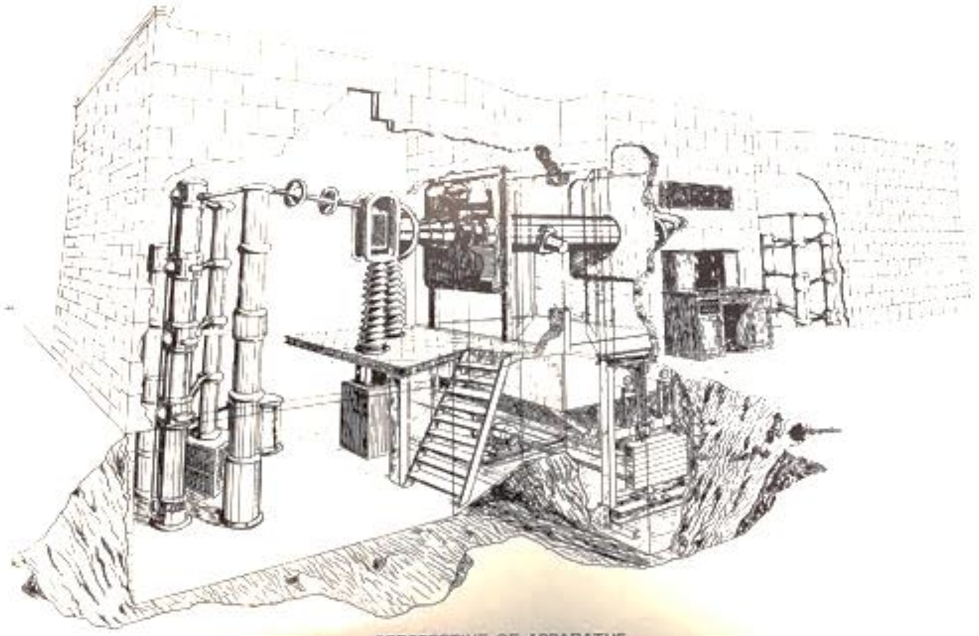
A building had to be specially provided with the appropriate radiation protection.
This "Mozelle Sassoon Unit" was officially opened on 10th December 1936, having been funded by a donation of 15,000 pounds from Mrs Mozell Sassoon. The research department of Metropolitan-Vickers Electrical Co Ltd in Manchester installed equipment to operate at 700kV in 1936. But the tube became unstable in use (Allibone, Bancroft, and Innes. J Instn Elect Engrs 1939; 85: 657). However, by 1938 the plant was operating at 1MV, and by 1948 then had worked for 10,000 hours (including disruption from bombs and V-weapons! From the paper (G S Innes Proceedings of the Royal Society of Medicine May 21st 1948 : "The

Million-Volt X-ray Plant-Its Development and Application"): "At the commencement of the war, the department was closed for 3 months, but during the rest of the war, although the department lost its ceilings, windows and doors three times, and part of its roof another time, the plant functioned……; sensitive relays and mechanisms damaged by concussion and vibration being temporarily locked in, by match sticks, until patients' treatments were completed for the day".

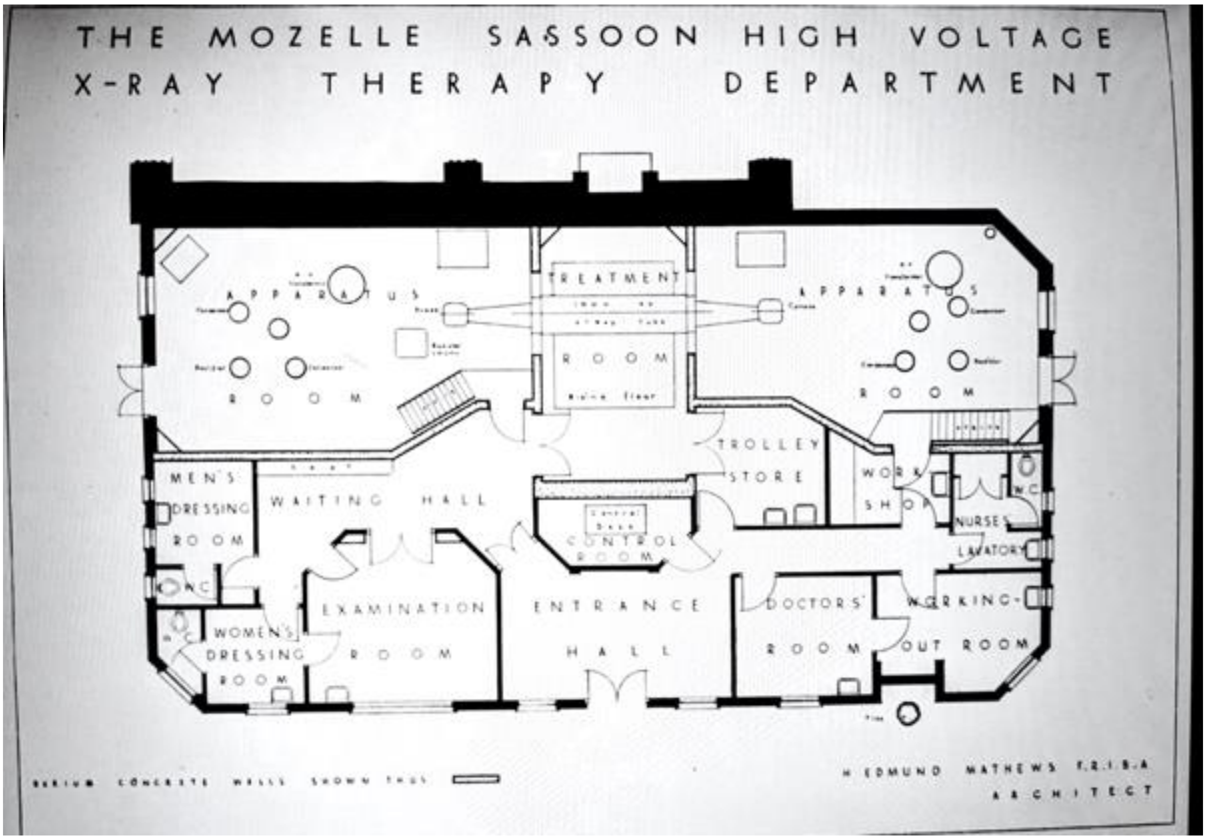
It was housed in the North Wing of Barts , next to the great hall. (The church of St Bartholomew's the Less can be seen behind the new building.

Description: (Figs below Room diagram ; and x-ray tube]
The tube (figure 2: 32 feet long , weighing 10 tons) and could a direct beam from pointing vertically downwards to 110 deg upwards (see similarity with Frank Farmer thinking for Newcastle linac 1954 below).

Protection around tube: 6inches of lead (weighing 8 tons) so that at 1MV 4.5mA the x-ray leakage into the room is only "one half of tolerance dose (0.5R per week). [The most recent regulations in the UK limit ***annual dose*** to workers to 20mSv (2R) and to the public 1mSv (0.1R)]



PERSPECTIVE OF APPARATUS



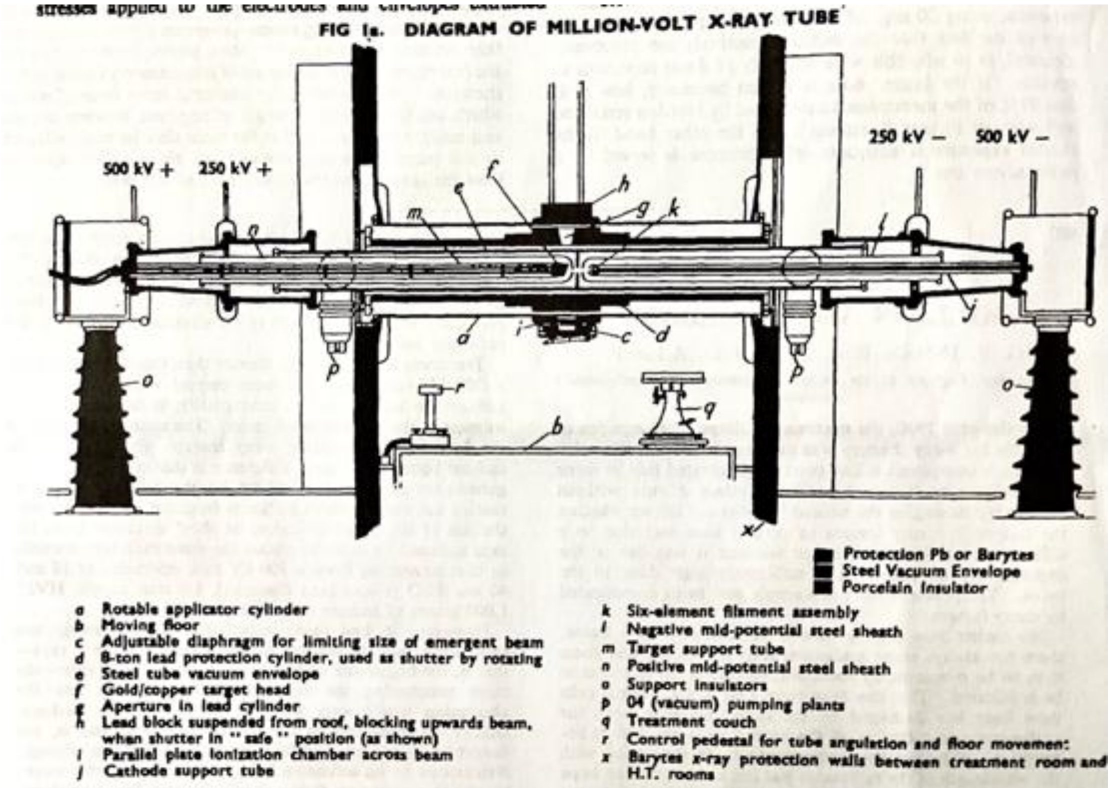
George Innes was fond of comparing this set with radium : “not quite as hard as the gamma rays from radium, but equal in intensity, under the same geometric conditions, to 7000gm of radium” (I believe the maximum radium ever used in a “radium bomb” was 50g).

Generators.
These were housed in two separate rooms (see plan of room).

The high voltage was supplied by two 500kV Cockcroft generators using 4 continuously evacuated thermionic rectifiers, operated from the 3 phase mains.

X-ray Beam Limitation.
"From our early experience with applicators at 700kV it was apparent that at 1MV and 1 metre FSD, applicators would be too heavy to handle. An adjustable diaphragm was constructed fitted with a light beam device which indicates the x-ray field size, shape and position" This was a remarkable piece of engineering (compare with modern Multileaf Collimators (MLCs) on todays linear accelerators?). It allowed fields of any size from 4x5cm to 40x40cm in cm steps.

This also contained a light beam which projects onto the patient's skin.



Room protection.
Wall built with 125 tons on interlocking barytes bricks "preventing the egress of x-rays that it is possible to store films within a few feet of the treatment room"). The Great Hall wall was found to be 3ft thick. The surrounding areas were limited to half tolerance dose (approximately 0.5R per week; the present day dose limit for radiation workers is 2R per year, and for members of the public 0.1R per year???).

The tube was activated in the morning and run at 1MV all day. The rotation of the lead surround ensured that in the "off" position there was enough lead absorbing the beam to satisfy the protection limits at that time. The radiographers were limited to only spend 1 hour a day in the room. They wore "film badges" (dental films) to check the dose they received.

Air Conditioning.
In the treatment room the plant provided 10 air changes per hour; and in the generator rooms 5 air changes per hour.

Control Room.
The patient was viewed using a clever arrangement of curved mirrors. The radiographer side of these can be seen in the control room photograph.
Providing the treatment room doors were shut (and interlocked) the whole of the lead cylinder could be made to rotate from the control desk. Automatic interlocks stopped the rotation when the x-ray aperture is aligned to the diaphragm on the outer sheath.

Dose Control.
Just behind the diaphragm was mounted a 3-plate ionization chamber giving a signal through an amplifier to the meters on the control panel to indicate both dose rate and given dose .

Control Room showing: Dose rate meter; microphone (communication with patient; simple circuit diagram with lights to show any faults; the periscope system of mirrors to view the patient on the other side of the barrier)

Voltage source.
The high voltage for the tube is supplied by two 500kV Cockcroft generators (transformer, condensers (capacitors?), 4 continuously evacuated thermionic rectifiers, and operating from the mains (3 phase)

Vacuum System.
Oil diffusion pumps (compare with Newcastle 4MV Linac-1954, see below); need to remain vertical) and rotary pumps.

Beam Characteristics.
Depth Dose: about 50%[This is really important; those centres that couldn't achieve 1000kV x-ray energy would not benefit the treatment of deep-seated cancers….see above]

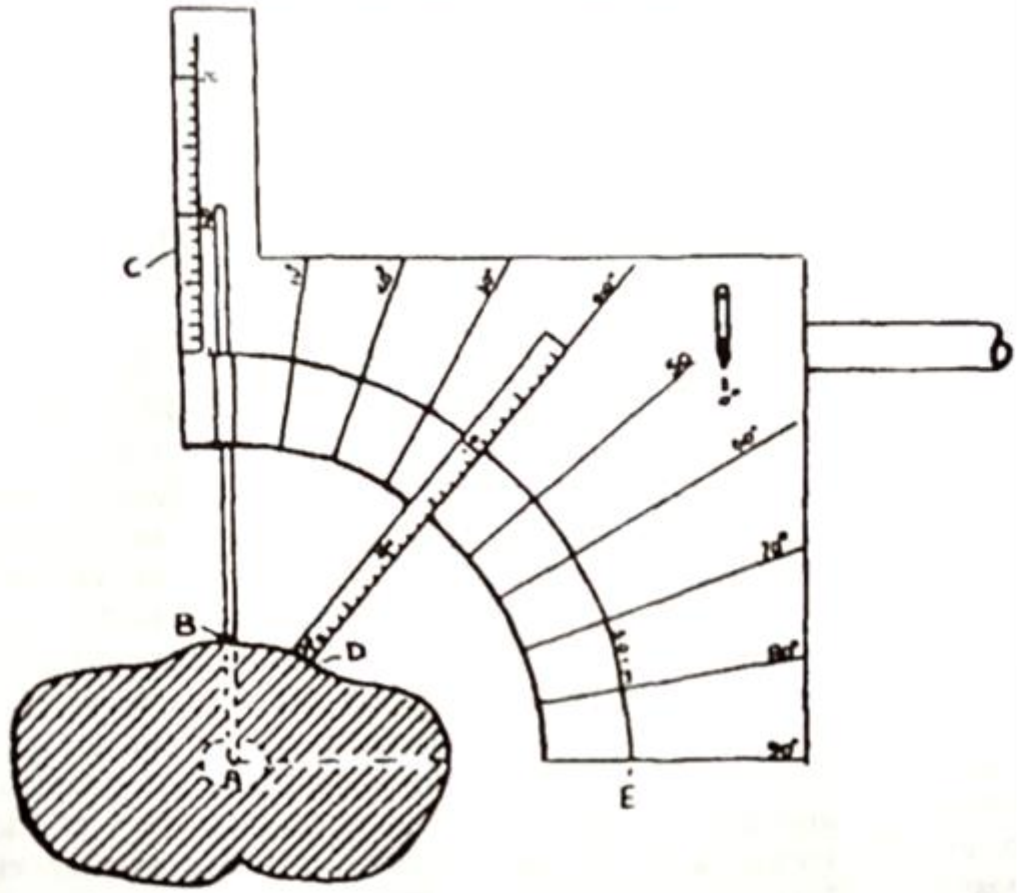
Beam "sharpness" .
Innes warns of the penumbra problem (the focal spot size is given as 2.5cm); but in this paper doesn't find a solution???

Modifications possible compared with 200kV treatments.

1. "It becomes possible and economical to employ multiple small fields, even through the remote lateral skin surfaces".
2. 2. For carcinoma of the larynx only two fields are necessary at 1000kV , where 3 fields were used at 200kV
3. For carcinoma of the rectum the difference between 1000kV and 200kV can be seen in the figure : the 370% contour surrounding the tumour compared with the 250% contour with 200kV.; and there is a more rapid fall –off in dose , so causing less damage to the surrounding organs.
4. All this allows a higher dose to be given to the target volume; in particular the 200kV plan to high dose was limited by the skin dose.
5. (but see penumbra issue?)

Aids to accurate technique.
1. X ray photography: Transmission radiography was used …50years before it became routine in modern megavoltage therapy. George Innes noted that "The films were slightly improved if 2mm of lead is placed between the patient and the film " (BMB ref1946). (Note: Cassettes used in 1970s megavoltage verification films used a copper lining for similar *"need for build-up*" reasons)
2. A light beam indicating the position and size of the x-ray beam was used (see Newcastle linac below)
3. A Pin-and –Arc device (figure below) developed by Dobbie 1943) was used for all angled beams

FIG. 6. PIN-AND-ARC DEVICE



Other
From the 1948 article (Proceedings of the Royal Society of Medicine 41; 691) After many modifications the tube was put into operation in 1939 1MV 4-5mA. Operated day and night for 95,000 hours. The longest period of breakdown has been one afternoon (see modern linac performance!!). It operated until 1965; when other high energy equipment was already in use: Cobalt 60 units and Linacs: see below.

Medical Uses.

Summary of the Physical Treatment Advantages of 1,000 kV X-rays Due to the increased depth doses, other physical factors and reduction in the skin reaction, the following advantages are obtained:

(1) Fewer fields can be used to deliver the lesion dose required and hence we obtain a simplification of the treatment plan with a resulting gain in accuracy.

(2) Alternatively it is possible to reduce the dose level to some or all of the multiple fields.

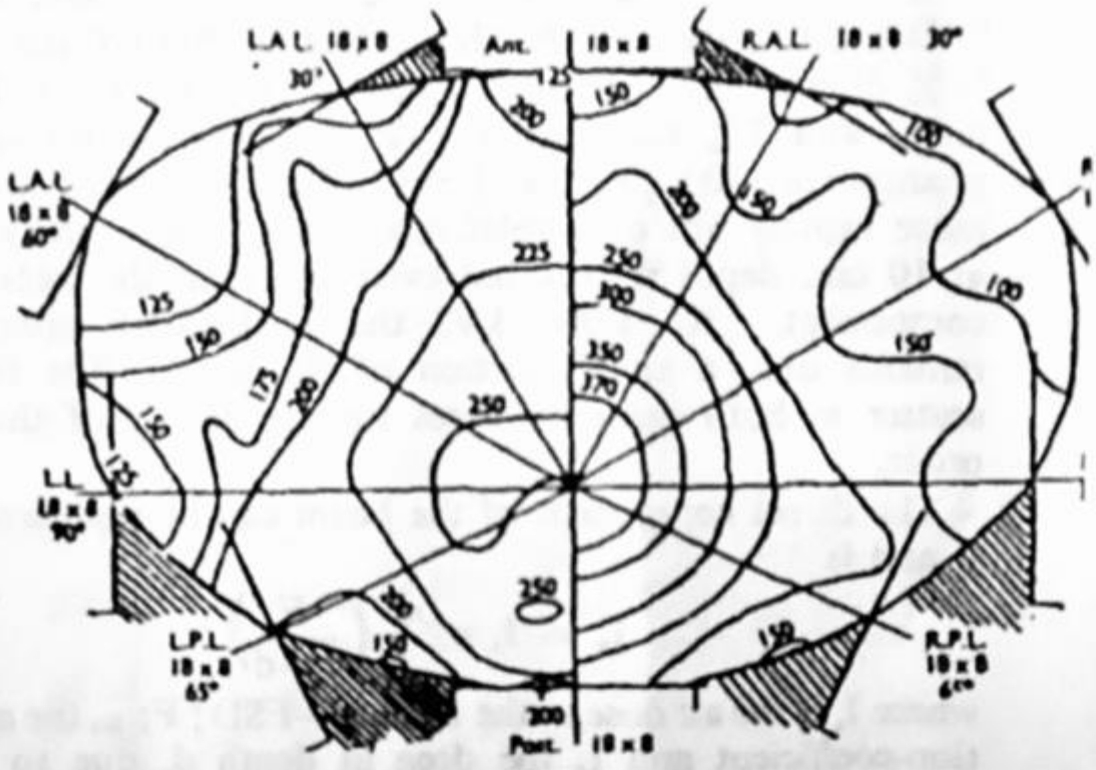
(3) It is possible either to reduce the dose on fields passing through easily upset organs or alternatively in some cases to avoid irradiating them altogether, attaining the necessary tumour dose by a less efficient routing of the beams to the lesion.

(4) In nearly all cases, 6,000 r can be delivered to the lesion in five weeks, no matter how deeply seated it is or how large the patient.

(5) By careful planning the dosage level can be made to fall off rapidly outside the volume to be irradiated, reducing the ill-effects on the patient.

(6) It will be noticed that no attempt is made to avoid beams passing through bony structures, since bone absorption at a million volts is very little greater than tissue, with the result that the isodose plans are a very near approach to the actual dose distribution in the patient, irrespective of whether bone is present or not. Also round the bone there is only a negligibly small trace of ionization in excess of that indicated by the r dosage level of the isodose.

FIG. 5. ISODOSES ON A TRANSVERSE SECTION A CARCINOMA OF THE RECTUM



a. 10–18 x 8 40 cm. FSD fields: with 200 kV DC. x rays (HVL 2.0 mm. Cu)

b. 10–18 x 8 100 cm. FSD with 1,000 kV DC. x (HVL 9.0 mm. Cu)

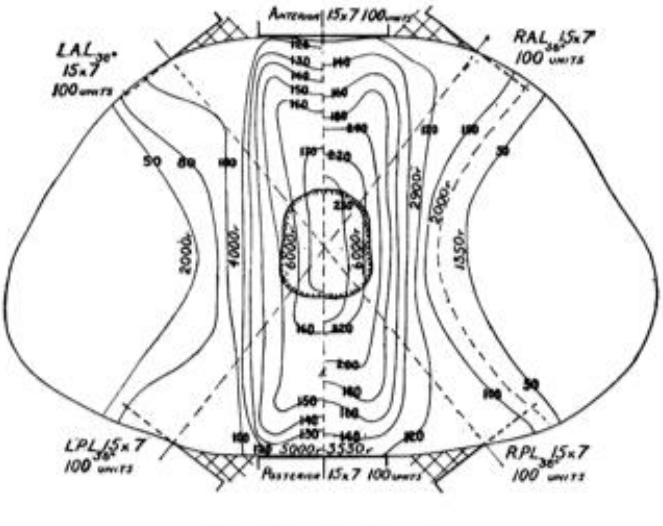


FIG. 10.—Ca. Œsophagus.
Left: Treated by 250 kV, 1·5 mm. Cu H.V.L., 50 cm. F.S.D.
6,000 r $D_T \equiv$ 4,000 r/field $\equiv$ 5,000 r D_S.
Right: Treated by 10^6 V, 9·3 mm. Cu H.V.L., 100 cm. F.S.D.
6,000 r $D_T \equiv$ 2,760 r/field $\equiv$ 3,530 r D_S.
(Maximum possible = 7,600 r D_T.)

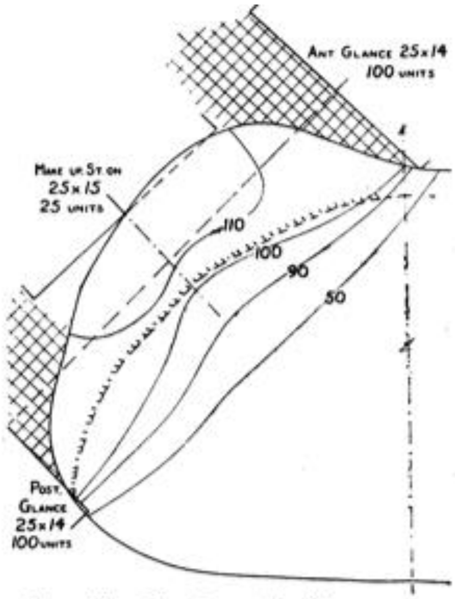


FIG. 11.—Ca. Breast L. (Transverse section). Treated by 10^6 V, 9·3 mm. Cu H.V.L., 100 cm. F.S.D.

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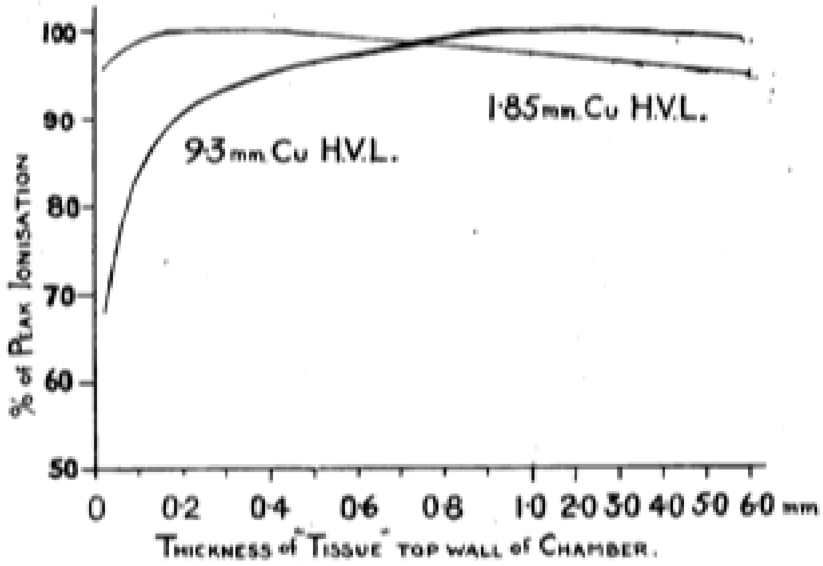
The NKI team noticed there was no skin sparing. George Innes (in his Brit Medical Bulletin 1946 paper) noted under the subheading "Alteration in Skin Reaction: Tests were carried out on corresponding skin surfaces on patients with x-ray beams of identical dimensions under the same physical conditions except for the beam qualities. The control beam was one of 300kV, while the experimental beam was 1000kV (HVL 10mm Cu). The dose required in one sitting to produce the same skin reaction was 50% greater with the 1000kV than with the 300kV". This is an extraordinary statement given the lack of knowledge at that time; but demonstrates the skin sparing of the megavoltage beam .

The term "build-up" wasn't used at that time. It is due to the forward emission of the Compton electrons. The approximate 1mm build-up achieved with the Barts 1MV set (see below) appears to be sufficient to reduce the does to the epidermis and to some extent the dermis, markedly reducing skin reaction.

Using existing knowledge of all build-up depths (including Cs-137 and Co-60) we have arrived at an estimate of a build-up depth for the Barts 1MV unit of 0.8mm **(but see also George Innes measurements of dose versus first few mm of depth)**



Mayneord (below) gives a higher value. The slope of the build-up curve is fast to begin with; then , from 95% to 100% a very slow increase. For purposes of understanding erythema dose the 1mm figure makes more sense?)

Mayneord 1950 (see FT Farmer paper 1962):

Institution Discussion (re 1939)
Ralph Phillips became chief assistant at Barts in 1932, working under Dr NS Finzi who had pioneered treatments with supervoltage therapy. They early produced a complete regression in an inoperable rectal carcinoma. His book (Supervoltage Radiotherapy…) and work were widely acclaimed in UK and USA. As early as 1938 he produced a complete regression in an inoperable rectal carcinoma. He moved to USA to work at Memorial Hospital from 1945 to 1968.

"I have had the privilege of using this apparatus at St Bartholomew's for nearly 2 years, during which time over 1500 individual treatments have been given….I should like to emphasize its absolute dependability-during this 2 year period I have only twice been prevented for giving treatment as planned. A given set of conditions can be maintained absolutely constantly ……and there is never any doubt as to the amount of radiation which is being administered".

A further point is the simplicity of the apparatus; it is quite fool proof.
The increasing use of technical apparatus and instruments of precision in medicine might lead one to think that medicine is a matter of pushing the right button or turning on the right tap, but I would emphasize that this is not the case. Radiotherapy, in spite of using these very precise instruments, has not become a mechanical science; it remains a part of the art of medicine, and each patient is an individual to be treated primarily from clinical knowledge, which is based on experience and observation.

The installation of the 1 000 000-volt X-ray tube at St. Bartholomew's Hospital may well mark an important step forward in the campaign against cancer.

Also at this discussion both Dr WV Mayneord and Dr NS Finzi commented on the safe and reliable nature of this 1MV unit compared with those they had seen in the USA.

High Energies after 1950
It is amazing that the 1MV unit continued to function so well, treating many patients until 1960s. During the 1940s-1950s efforts were made to find: a) alternatives to the radium bombs (which could only be used at short distances because of the limited amount of radium available (usually only 3-5g…or Curies); b) alternative means of accelerating electrons instead of direct high voltages.

Post Radium with radioactive sources.

Cobalt 60
On 1 January 1947, the super-secret Army Manhattan District had become the civilian-controlled AEC, which then controlled the Oak Ridge reactor and made isotopes for the public and bombs in secret. The AEC in 1947 authorized three hospitals for research in the use of radioisotopes in treating cancer. In addition to ORINS (Oak Ridge Institute of Nuclear Strategies) in Knoxville, Tennessee, radioisotope research hospitals were approved in 1947 for Brookhaven, NY, and Chicago (Argonne). Dr.RL Clark and Dr M Brucer (on medical board of ORINS) arranged for a dialogue to begin between Dr. Brucer and L.G. Grimmett (from UK) in the summer of 1949. By August of 1949, Grimmett had a tentative telecobalt design which he presented to Brucer at ORINS. By September 1949, Drs. Clark and Brucer were proposing collaboration on telecobalt.

(Ref: Report on a mission to Washington DC to attend a meeting on Cobalt 60 called by the AEC Feb 12-14, 1950)

33 Physicians and physicists met together on 13th Feb 1950 and in July 1950 Dr Fletcher (chief radiotherapist at MD Anderson 1948-1981 and author of "A Textbook of Radiotherapy" 1966) presented a paper in Paris at the 5th ICC. Advocating the use of Cobalt 60 for teletherapy.

However, it was Harold Johns who got ahead of the game and in August 1951 a source was installed in the Johns machine in Saskatoon (Johns HE et al 1951) Treatment began on 8th November . Johns reported a dose rate of 33R/min at 80cm. Another unit was delivered to London, Ontario for immediate clinical use on 27th October 1951.

In the UK the first cobalt 60 unit (the first in Europe) was installed at Mount Vernon Hospital in 1953 (presented by the BECC to MVH as a present to the country from a Canadian, Mr J W McConnell)

Figure 2. The Saskatoon Unit designed by Harold Johns and students, and John MacKay of Acme Machine and Electric of Saskatoon. From University of Saskatchewan, University Archives and Special Collections, University Photograph Collection, A-2244.

Caesium -137

England‘s J.S. Mitchell. M.D.. Ph.D., could not get cobalt-60 (his idea) from Harwell, ARE, so he persuaded his physics colleague at Addenbrooke’s Hospital, Cambridge, H.F. Freundlich (who had also served in Canada) to try a radio-iridium telegamma unit in 1949-1950. With a half-life of 30y (no need for source change, compared with cobalt) and maximum output of 16 r/min at 8 cm, it was more like teleradium than telecobalt.
(Edwin remembers that there was a short distance Caesium unit at Newcastle if 1967; mainly used for Head and Neck tumours since the depth dose and dose rate were not very high. I believe the activity was 1500 Ci.)

The characteristics of Cobalt 60 teletherapy units
A gamma-ray source emits two photon beams with energies 1.17MeV and 1.33Mev resulting in an average beam energy of 1.25 MeV (comparable to a 4MV x-ray, see Newcastle linac below). Used with at a typical SSD (Source Skin Distance as opposed to FSD : Focus Skin Distance for x-ray sources) of 80cm .
The depth dose at 10cm depth 56% ; build-up depth 15mm.
For a 5000 Ci source the dose rate is about 80 R/min [We have used R instead of cGy throughout this paper to avoid confusion, even though the use of ‘R” was abandoned in 1965 in radiotherapy to the “rad”]

The half- life of Cobalt 60 is 5.27years. It was usual to change the source every 2.5-3years to avoid the dose rate getting too low for patient treatments. This was an expensive (and difficult /dangerous procedure …(see accident ref).
The source size, typically 2cm diameter, resulted in a large penumbra; this could be moderated by using penumbra trimmers. Most UK centres found that they mainly used cobalt 60 for tangential fields for breast radiotherapy . However, once low MV Linacs were common, 5-6MV x-rays were used for this form of treatment ; and so cobalt 60 sets are no longer used in the UK. However, they are still used in countries where maintenance of the complicated linear accelerators is a problem (also ref: new cobalt 6o unit).

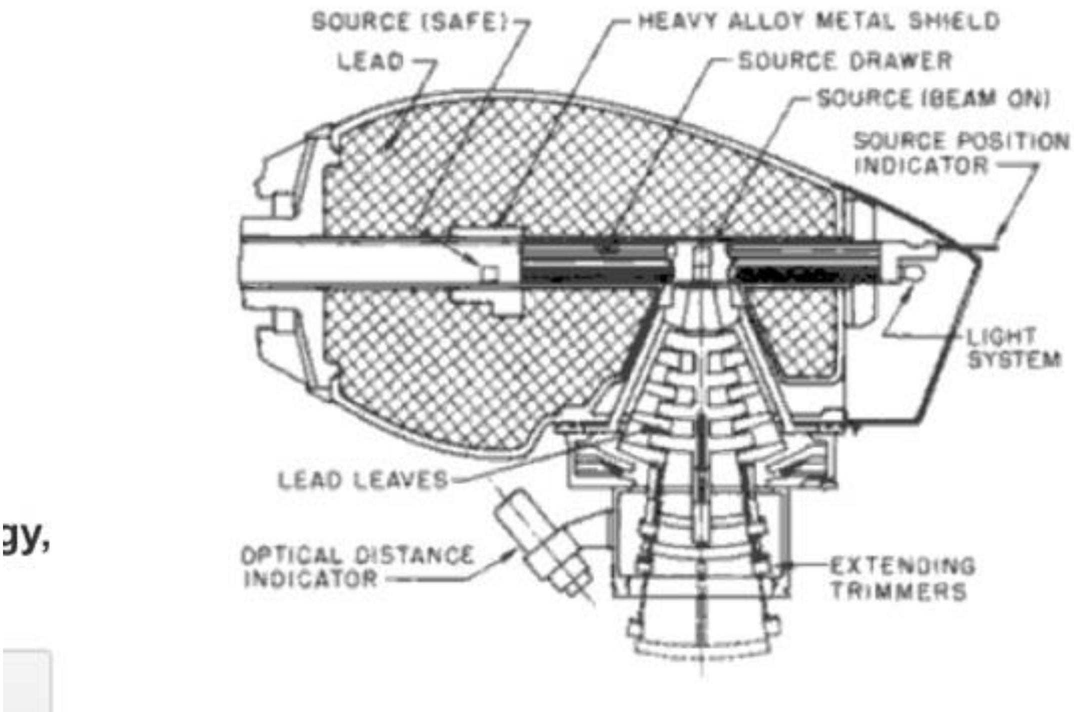


Fig. 7 AECL teletherapy head.

Viewing the patient.
The problem with direct viewing of the patient is the room wall thickness; even secondary barrier (the primary beam must not hit the secondary barrier) is typically 1metre concrete for cobalt 60 ; 1.5 m for 4-6MV.

Direct viewing could be done with many plates of lead glass, but with poor vision. Alternatively some centres used glass ended tanks containing Zinc Bromide (the highest density clear liquid). Also, simple periscopes could be used consisting of two mirrors mounted in the concrete wall for cobalt 60 energy.

Frank Farmer procured a cast-off submarine periscope for the Newcastle 4MV linear accelerator at Newcastle.

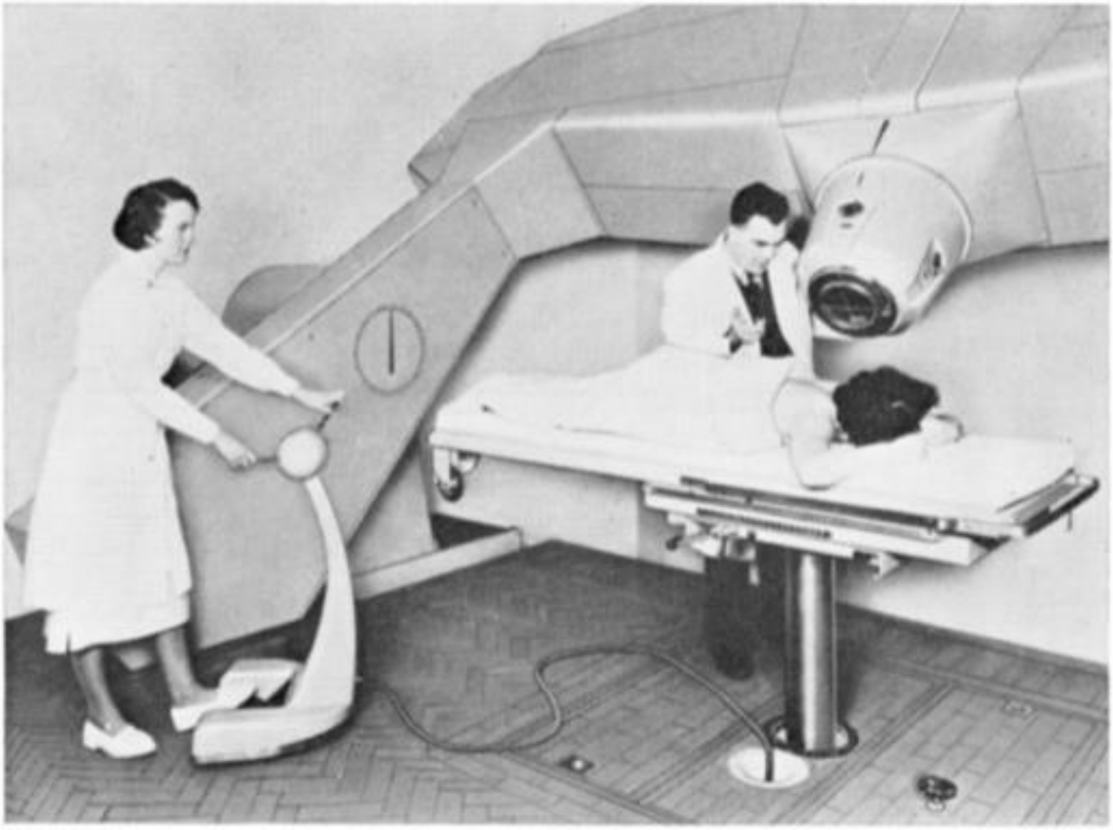
4MV linear accelerator in Newcastle-upon-Tyne (1953) (MJ Day and FT Farmer Brit J Radiol 1958)

This was one of the first linear accelerators to be used clinically in the UK. (and one with which Edwin had direct experience in 1967 until it was removed).

It used a long 10cm waveguide (microwaves of 3000MHz frequency) and feedback loop in a travelling waveguide.

Vacuum System: an oil diffusion pump with a "backing rotary " pump (NB replacement of filament every few months takes 20 minutes to restore the vacuum).

The gantry (see figure) is mounted on large bearings 13.5 feet apart, counterbalanced at each bearing and driven by a variable speed motor controlled from the pedestal seen in the figure. The treatment room floor is stepped downwards behind the machine to a depth of 3 feet allowing the beam to be directed upwards at an angle of 30 degrees (very useful for breast/chest tangential beams), so that the range of gantry movement is 210 degrees.



g. 5. The 4 MeV Linear Accelerator (Mullard) showing the single pillar treatment couch and isocentric mounting.

X-ray head. (figure below)
Surrounding the target there is enough lead to attenuate the unwanted x-rays that emerge towards the walls and ceiling of the room (this ensures that less concrete /building materials can used in the walls (secondary barriers) of the room. The primary collimator is made with tungsten or tungsten alloy; this reduces the x-ray dose rate in unwanted directions by at least 1/1000.
Diaphragms are made with 4 inch (10cm) lead blocks on pivots.

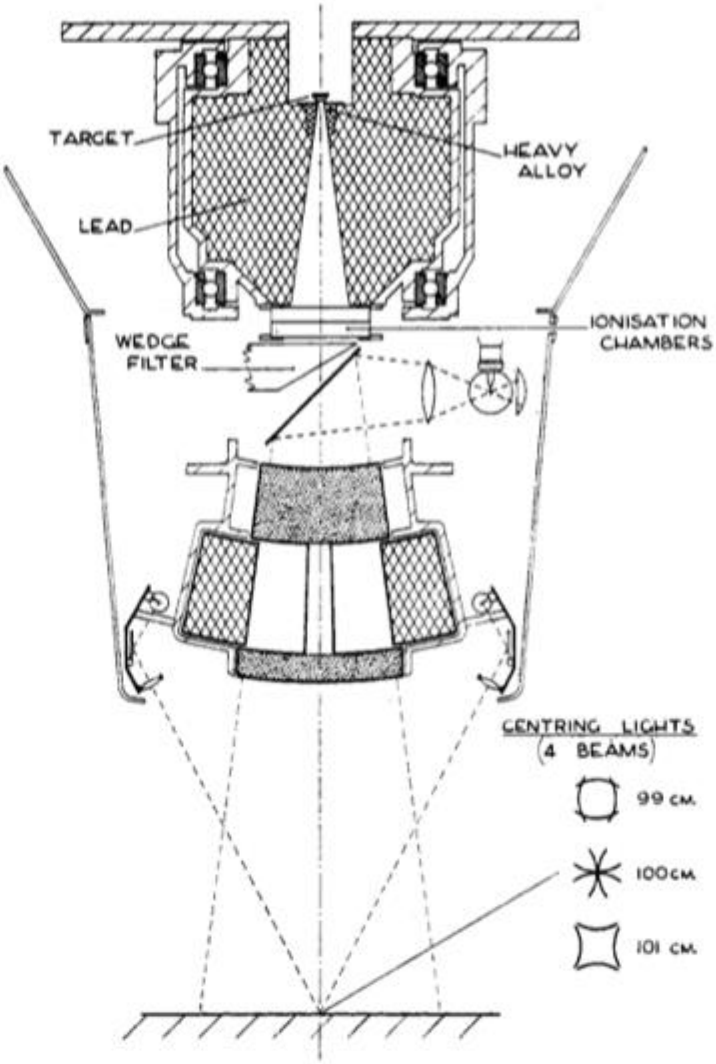


Fig. 6. The beam defining systems on the 4 MeV Linear Accelerator (Mullard) showing the optical system for field illumination and the 'range finder' lights for centring and distance indication.

Optical System.

1. Lamp and mirror to show the field size on patients skin.
2. "Dam-buster lights" to determine the (fixed) focal –skin distance (100cm)

Treatment Couch.
One of the first "Iso-centrically " mounted couches (Howard et al 1950)..definition : the point is space where the centres of rotation of the gantry, treatment head, and couch meet; making it much easier to set up the patient so that all beams pass through the target.

Beam Characteristics.
The % depth dose at 10cm depth for a 10x10cm field was about 63%. The build-up depth was 10mm. (Cf. later Linacs: 6MV % DD 67% Build up depth 15mm; 8MV 73% Build up depth 20mm)

Letter from Bill Ross (ref WM Ross and MJ Day Brit J Radiol 1981)
Lifetime of 4MV at Newcastle : 1st patient Dec 3rd, 1953; last patient May22 1981
18,272 course of treatment; more than 600,000 fields.

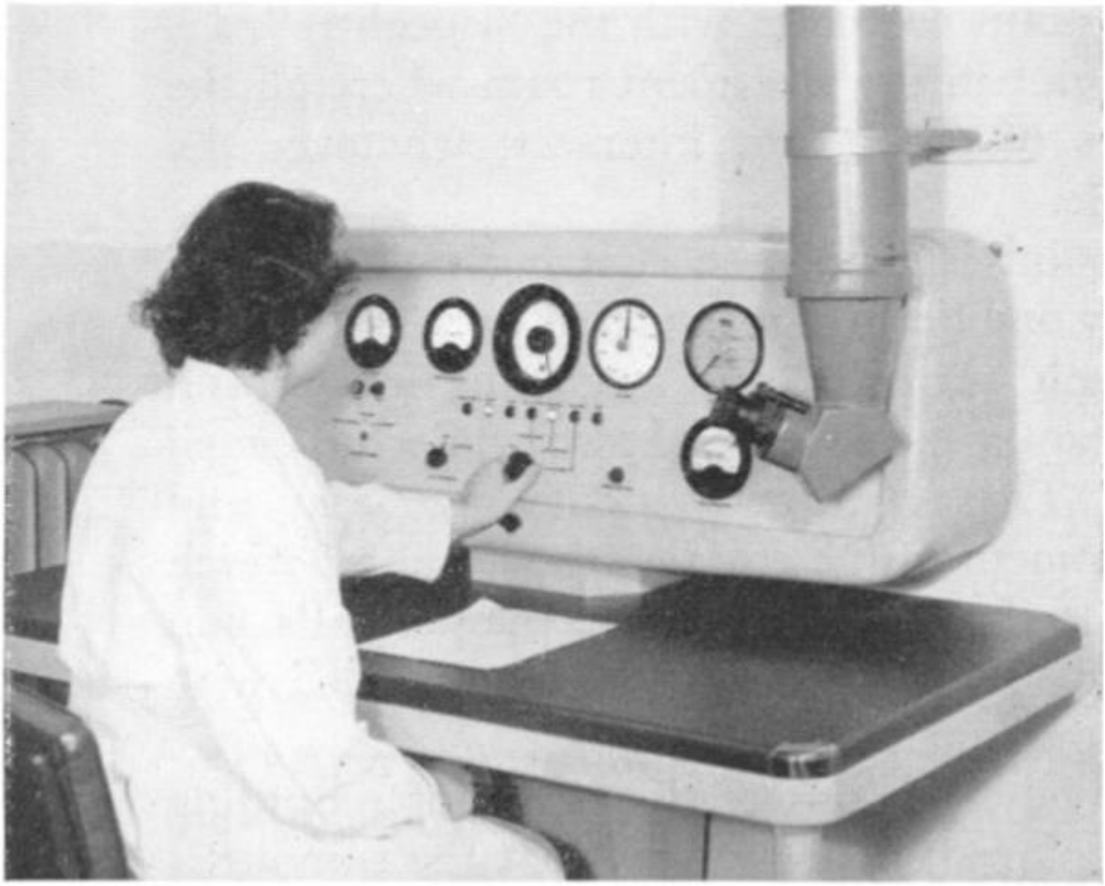


Figure: Control desk for 4MV linac with dose and dose rate meters; and periscope for patient viewing.

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