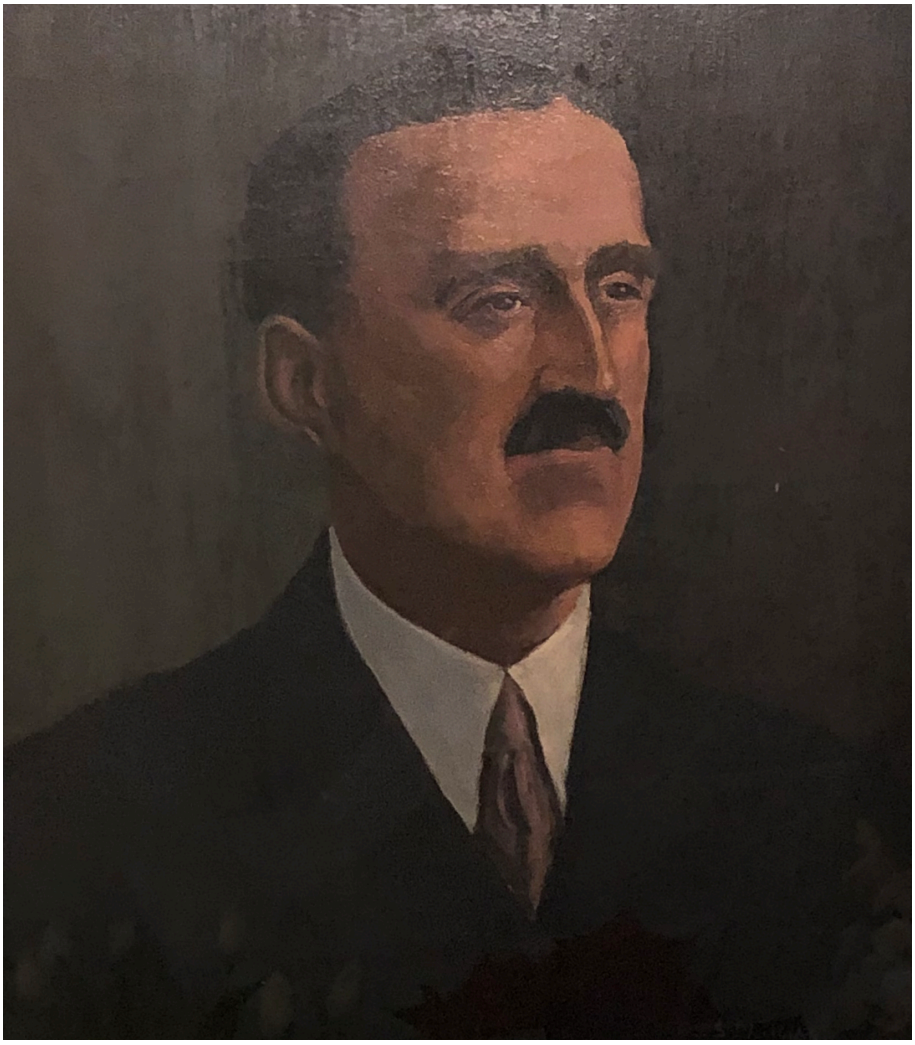
The Invisible Light



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The Invisible Light (46)

Contents:

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Editorial.

I had anticipated that 2020 to be about celebrating the Centenary of the Society of Radiographers and the 100th birthday of my old friend Marion Frank and not about being ay home at a time of COVID-19. However there is a certain 'fearful symmetry' (as William Blake might say) in that the Society of Radiographers was founded when the world was recovering from the influenza pandemic of 2018-2019.

This edition of The Invisible Light has much of interest to read. Barbara Robinson gives an account of Memories of Mr. Ashworth and her student days at Bromley Hospital. Francis Duck gives us a long and interesting account of Archibald Reid, Frederick Harlow and Charles Phillips and the War Office X-ray Committee, 1915-1919. Sir Archibald Douglas Reid (1871-1924) was a remarkable man. Reid was a radiologist at St. Thomas' Hospital in London, and his portrait on the front cover was painted in 1937 by Charles Phillips (and is from the collection of the editor). The main risks to radiologists have traditionally been related to three causes: overexposure to radiation, electrical accidents, and hazards associated with the chemicals used in film processing. Being cursed by a mummy would not come particularly high up on the list of dangers for most of us, but this was the reputed fate of Sir Archibald as the following article 'The radiologist and the curse of the mummy' (Aunt Minnie Europe, January 6, 2020) shows: https://www.auntminnieeurope.com/index.aspx?sec=sup&sub=xra&pag=dis&ItemID=618233 (paste this link into your browser).

Please send me material for the next issue (November 2020). If you come across any interesting books then consider writing a short review. I still come across new books. I recently found an excellent book by Stephen Dewing on 'Modern Radiology in Historical Perspective' (Charles Thomas, 1962), which was based on lectures that he gave to trainee radiologists at Bellevue Hospital in New York in 1958-1959.

Adrian

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Edith and Florence Stoney, Sisters in Radiology (Springer Biographies)

Hardcover – 15 Jul 2019
by Adrian Thomas, Francis Duck.
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Language: English
ISBN-10: 3030165604
ISBN-13: 978-3030165604

Review of Edith and Florence Stoney, Sisters in Radiology

by Liz Beckmann, Chair of the British Society for the History of Radiology.

This is a fascinating book which takes us through the lives of two incredible women at the end of the 19th and early 20th century. It tells the story in the context of the time and describes the other people and situations happening around them and influencing their lives.

Florence and Edith Stoney were born and brought up in Dublin in a very open minded and stimulating family setting. The book gives an insight into the environment that they grew up and were educated in as well as the influence of the Suffragette movement on them.

Both of these sisters were pioneers, Edith was the first woman to practice Medical Physics while her younger sister Florence was the first woman to practice Radiology. Their Careers were very different, while overlapping in their involvement in the early pioneering days of X-rays.

By the outbreak of the 1st World War Florence had 13 years' experience of Radiology and was already very experienced, and it was around this time that Edith decided to become more involved in Radiology.

At the outbreak of WW1 it was a challenge for them to be allowed to contribute and the book describes this and their different experiences in France, Salonika, Belgium and Serbia during the war including their Influence and interaction with others and the conditions they had to cope with.

The stories of the challenging environments that they found working with the early X-ray units deployed in WW1 is particularly well described including the description of the equipment at the time and the challenges of setting it up in a war zone.

This wonderfully written book helps the reader really understand the two sisters and the significance of their achievements, particularly their major contribution to early mobile radiography.

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The Bromley School of Radiography

By Adrian Thomas, formerly Consultant Radiologist, Bromley and District Hospital.

I hope that you find the following piece about the Bromley School of Radiography to be of interest. I met Barbara Robinson, who wrote the piece, when I gave a talk to the Bromley Branch of the NHS Retirement Fellowship. It's so important to remember our Schools of Radiography and not nearly enough has been written about them. Adrianne Finch edited a book about the Middlesex Hospital Schools of Radiography (Finch, 2012) which makes excellent reading. There should be more such volumes.

William John Ashworth was a remarkable man and was spoken of well by those who remembered him when I was appointed consultant radiologist at Bromley Hospital in the mid-1980s. John Ashworth was Superintendent Radiographer at Bromley Hospital, Bromley, Kent and was Teacher Principal of the Bromley School of Radiography. John was very active in the Society of Radiographers, and in 1952 before he was their President he wrote a letter offering to resign from representing the SoR from Committee D of the Whitley Council because of the 'thankless and humiliating task' which the Society's representatives faced when they negotiated with the Management side This was particularly the case with emergency (on-call and stand-by) duties. Ashworth thought that 'the Whitley machinery has become little more than a vehicle for accepting any indignity the Management Side choses to impose' (Jordan, 1995). Council noted his letter, and asked him to accept the decisions of the Council, and with reluctance would further reconsider his decision (Moodie, 1970). He was Honorary Fellow and was President of the Society of Radiographers (SoR) from 1955 to 1956. In 1964 he presented the 27th Stanley Melville Memorial Lecture.

The Bromley School of Radiography had been founded by John Ashworth and Bromley radiologist Dr Glendenning. It was located at Glendenning House in Bromley Common which was close to the hospital. There were many distinguished former students including Audrey Paterson, who was President of the College of Radiographers from 1993 to 1994 and who became Professor of Radiography at Canterbury Christ Church College, and pioneer of radiographer reporting; and Michael Jordan who became Assistant Secretary to Kenneth C. Denley, the Secretary of the Society of Radiographers, becoming Chief Executive and General Secretary when Mr Denley retired in January 1976.

In 1965 Ashworth and Jaundrell-Thompson wrote a highly successful book on X-ray physics and equipment (Jaundrell-Thompson & Ashworth, 1965). The book was aimed at those studying for the Membership Examination syllabus of the SoR and the hope was expressed that it might be useful for the Fellowship examinations. Jaundrell-Thompson was Principal Superintendent Radiographer at St Bartholomew's Hospital and was Honorary Fellow of the Society of Radiographers. He was SoR President from 1952 to 1953, and in 1958 gave the Third Welbeck Memorial Lecture.

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Memories of Mr. Ashworth and my Student Days at Bromley Hospital.

By Barbara Robinson (née Reed)
(written in March 2012)

I was a student radiographer at Bromley Hospital between 1957 and 1959, my fellow students being Janice Brown, Diana Smith and Frances Jacobs. The School of Radiography there had been set up several years earlier and was by then well established. Mr. Ashworth was the principal of the school and taught us physics, apparatus construction and photography and we also had lectures in anatomy and physiology from Dr. Glendinning and technique from Jeanne Dobbie (later Wheeler). I paid 50 guineas to the hospital for my training and had to buy my own uniforms. As we entered the second year of training our white dresses were going into holes due to the action of developer and fixer splashes. Matron complained about the scruffy appearance of the student radiographers but as we were living on small grants and had no money to buy new uniforms the hospital eventually agreed to provide them.

While still at school I had no idea of what career I wanted but radiography seemed vaguely interesting. It was suggested that I contacted Mr. Ashworth to find out more about it and once he found anyone who was remotely suitable to train they were not allowed to escape! Before I left, my name had already been put down for the next training course which started just before my 18th birthday. Similarly, Janice had really gone to Bromley Hospital to enquire about doing occupational therapy but was completely won over by Mr. Ashworth's enthusiasm for radiography. We both agree that we have a lot to thank Mr. Ashworth for as we couldn't have found another job in the world that we would have enjoyed as much. All 4 of us in that year carried on working in radiography until we retired and can look back on very satisfying careers.

My overriding memory of my student days is how scared we were of Mr. Ashworth! He was a strict disciplinarian of whom we were very much in awe. We were certainly kept in our places as the lowest of the low and seemed to do an inordinate amount of cleaning around the department. Cassettes were cleaned on Friday afternoons – I remember how we got sleepier and sleepier as the afternoon wore on, due to inhaling the fumes of carbon tetrachloride which we used to clean the screens with! – and Saturday mornings were spent at the sink scrubbing frames. On one fateful day I decided to tidy up the screening room and lowered the tilting table, not noticing that there was a stool in the way, with disastrous results. Everything ground to a halt and fuses blew everywhere. I had to pluck up courage to find Mr. Ashworth and confess my sins, telling him in true Frank Spencer style that I'd 'had a little accident'. After the engineers had been and put everything right Mr. Ashworth shouted down the corridor to me that that little episode had cost about £20, a small fortune in those

days. I was mortified! This is something that I've never lived down and even today, more than 50 years later, there are still some people who never fail to remind me of it!

There is no doubt that Mr. Ashworth was a very good teacher. None of us were particularly gifted when it came to science, yet Mr. Ashworth actually managed to make us understand physics and apparatus construction, which was no mean achievement, and enabled us to pass the qualifying exams for the MSR diploma. Photography was only slightly easier to understand but I can remember poor Janice confusing two words when writing up her photography notes, causing Mr. Ashworth to bellow at her " Latitude is the property of films, Miss Brown – lassitude is the property of students!!" On Thursday mornings we had a tutorial session with Mr. Ashworth, during which we had to ask him questions. We were warned that if we ran out of things to ask then HE would ask US questions instead so we made very sure that this never happened! I think I can claim the record in our year for him giving the longest reply – as a past President, the Society of Radiographers was very dear to his heart so I asked if he could tell us something about it and his reply lasted the whole session. During our lectures he was always being called out to take phone calls from Mr. Denley about society matters, and on one occasion he was away for several weeks in the Far East (possibly Singapore) helping to set up a school of radiography there. I think he travelled there with Mr. Jaundrell-Thompson. While we were students at Bromley Mr. Ashworth suffered from Meniere's disease which caused attacks of giddiness. We couldn't help noticing that these attacks usually came on when there was a pretty girl close by for him to grab in order to steady himself!
My final exam was on 6th November 1959. It was the Viva Voce and I was horrified to discover that I had Miss K.C Clark herself as one of my examiners. She was very kind and gentle in her questioning, though. She asked me why lateral cervical spine views were done at 6 feet AFD, to which I knew the answer and could also have told her the page number of her book on which it appeared. She also asked me why we put replenisher in the developer and my friends maintain to this day that my answer was 'to top up the level' although I strongly dispute this!

Both Janice and I were honoured to be asked to stay on at Bromley when we had finished our 2 year training but we had already been offered jobs at Lewisham Hospital. I think it was a good decision for us to move on as I felt we would always have been regarded as students, besides I would have had to live with my 'Little Accident' tag! When we met other newly qualified radiographers at Lewisham who had trained in larger schools we began to realise what an excellent training we had received at Bromley. In our second year we had been sent to Farnborough and Beckenham hospitals to gain further experience and this had given us confidence. I well remember reporting to Mr. Monk, the Superintendent at Farnborough Hospital on my first day there and being told to go and work on my own in one of the x-ray rooms. "There's an intercom on the wall so, if you want any help, just shout!" The room had a make of equipment I'd never used before but luckily I soon got to grips with it and plunged into an extremely busy morning's work. The only problem was that someone else was checking my films so I could not judge how well I was doing. I just got a message via the intercom if anything needed repeating. I still have my student log book in which is recorded 'bronchogram, unaided'. Not many students could boast of having done that! It meant that when we qualified we were perfectly competent radiographers, able to tackle anything and work anywhere.

On my very first day at Lewisham I x-rayed a certain Mr. Michael Robinson who later became my husband – another thing I have to thank Mr. Ashworth for! I cannot honestly say that I remember Michael himself but I certainly remember his broken leg in the largest plaster cast I'd ever seen, stretching from hip to toe with the knee bent. I can still recall working out how I could get a proper AP view of the tib and fib by propping up the film and angling the tube.

I feel extremely lucky that I drifted into radiography, as it was a job I absolutely loved. I gained immense satisfaction from dealing with patients and producing 'pretty pictures' as we were taught to in our training. I retired at the age of 70, having been qualified for 50 years and seen amazing changes over that time. When I trained, CT, Ultrasound and MRI were yet to be invented and all the films were processed by hand in the darkroom (by Wally). I have had a very enjoyable and satisfying career so thank you, Mr. Ashworth, for starting me off on that road all those years ago.

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Marion Frank (1920-2011), a celebration.

We have two anniversaries in 2020 – these are the centenary of the formation of the Society of Radiographers and of the birth of Miss Marion frank.

Marion trained with her sister Ellen in radiography at the Royal Northern Hospital and was mentored by Kathleen Clara ("Katie") Clark.

Marion was Superintendent Radiographer and Head of the School of Radiography of the Middlesex Hospital. Her enthusiasm for life was infectious and she had many interests. She was a keen member of the Radiology History Committee that became the British Society for the History of Radiology.

Marion made many visits to the German Roentgen Museum in Remscheid-Lennep and introduced the current director Dr Uwe Busch to our history group here in the UK.

Marion would have loved to see 2020 – not that she was afraid to die – but rather that she would have loved to be able to celebrate the centenary of the Society that she loved so much. Marion is still missed by us all.

Adrian Thomas

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Archibald Reid, Frederick Harlow and Charles Phillips and the War Office X-ray Committee, 1915-1919.

By Francis Duck
bathduckf@gmail.com

In Charles Phillips' appreciation of his friend and colleague Archibald Reid, following his early death in 1924, he wrote: 'Possibly more about the work of the War Office X-Ray Committee will some day be made known' [1]. This was written almost one hundred years ago and very little knowledge has been added meanwhile. In this article I will trace the origins, formation, activities and aftermath of this Committee and the first centralised laboratory for medical x-ray equipment that it set up. Following the Armistice in 1918, all records of the Army Medical Corps, including those of the War Office X-ray Committee and its laboratory, were destroyed. It became a lost episode in the history of British radiology, apart from a brief summary in the *Official History of the War* [2].
Towards the end of last year, when I was preparing a short article about the Charles Phillips [3], I came across several files of his personal papers. These had been stored with his laboratory notebooks in the library of the Institute of Cancer Research at Sutton. Some are typed, some are corrected drafts and some are hand-written notes. Together they constitute a unique record of the formation and operation of the X-Ray Committee. It is on these papers, as much as on the consolidated Official History, that the following account is based.

Archibald Reid and Frederick Harlow.

The 2nd London General Hospital was one of five Territorial Hospitals that were opened in London during the first months of WWI. It was housed in St Mark's College, Chelsea and in an adjoining secondary school on Hortensia Road. The hospital opened in September 1914 and, by mid October, had already had received four hundred soldiers. The civilian radiologist Archibald Reid took charge of the x-ray department. He had moved from King's College Hospital to St Thomas's Hospital in 1912 to be in charge of the Electrical Department, quickly expanding its x-ray facilities. He was well respected and well connected, and had served as the President of the Electro-Therapeutical Section of the Royal Society of Medicine between 1911 and 1912. Phillips remembered that 'his predominant characteristics were activity, good sense and good humour', a natural leader who 'could look ahead and direct a policy' whilst leaving others to carry out the detail.

By November 1914, Reid had become attached to the War Office to give independent advice on the radiological facilities in RAMC hospitals. The situation of radiology in the army at the outbreak of war was neatly summed up by Thurston Holland: 'In July 1914, the schedule of army X-ray equipment was practically that which has been in use during the Boer War (which had ended in 1902) and few or no army medical officers were expert in x-ray work' [4].

What the War Office required particularly of Reid at this very early stage of the war was his advice, not on radiological practice, but on x-ray equipment. This advice was required by the officer in charge of the Medical and Surgical Supply Branch, Lieut-Col George B. Stanistreet, a military doctor who was now Assistant Director-General for the Army Medical Service. Stanistreet had a wide responsibility for all hospital

equipment and medical and surgical supplies, of which x-ray equipment was only one small part, and gained advice from several sources. For example, a three-man committee of eminent surgeons was also set up by the War Office, charged with standardising the surgical instruments authorised for use in military hospitals. Stanistreet also needed a sufficient supply of clinical thermometers, and the National Physical Laboratory was commissioned to test a number from each consignment.

As each hospital was set up, each one had made its own decision about which manufacturer's x-ray equipment to install. As a result, x-ray units had been bought from ten different suppliers (Table 1). Reid selected the widely used Butt equipment for his department in the 2nd London, as he had done at St Thomas's [5]. This general lack of standardisation was not compatible with normal military protocols, but the decisions had already been made. Greater central control became possible, however, in the design of a basic x-ray field unit, straightforward for inexperienced staff to operate, that could be easily transported to and set up in field hospitals near the front line. From late 1914, 'War Office Field Service Pattern' units manufactured by Butt were being supplied to front-line hospitals in France. The couch with its under-couch tube is shown in Figure 1. Illustrations of other items are given in an earlier article in *The Invisible Light* [6].

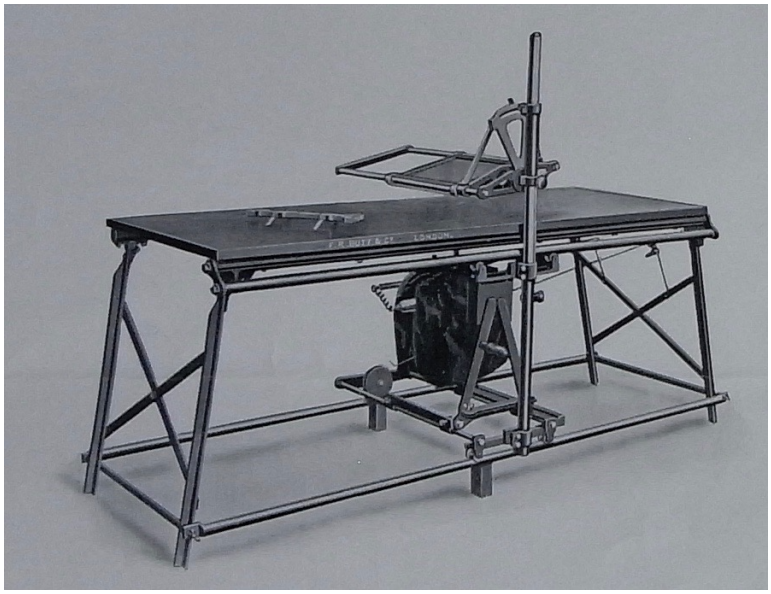
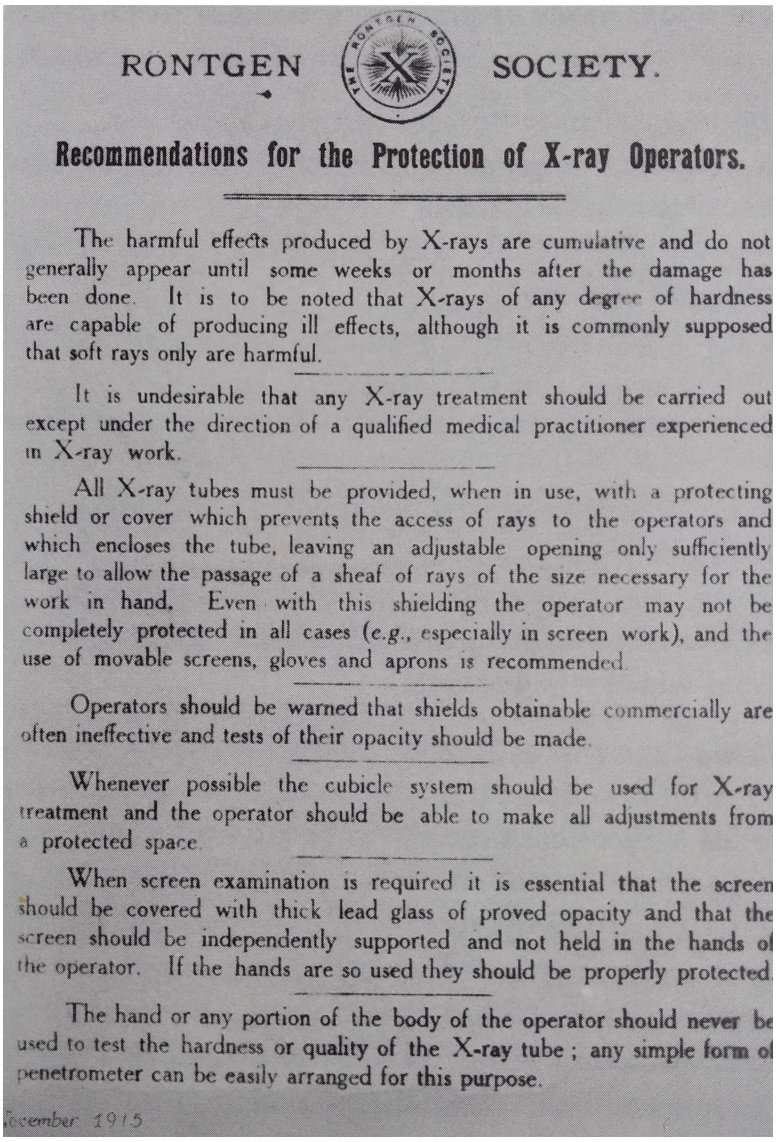


Figure 1 The War Office Pattern Field Service couch with under-couch tube and screen holder c. 1915

It was not long before several difficulties experienced with these Field Service Units were being reported back to the War Department. The generators supplied with them to recharge the accumulator batteries were unreliable. The staff had no training in operating the equipment. And, more worryingly, some operators were reporting bad skin reddening on their hands. By the summer of 1915, disquiet about aspects of military radiology was not confined to the War Office. At its meeting on 1 June, the Röntgen Society devoted much of the discussion to operator protection. A proposal was made that the War Office should supply one of their Field Service x-ray units so that the Society could demonstrate how best the operator could be protected [7] . At the same meeting, Sidney Russ, Physicist to the Middlesex Hospital, reported his tests on the protecting properties of lead rubber. The following day the Middlesex Hospital Board meeting noted that the Medical Research Committee had asked him to 'draw up rules to be observed by the x-ray operators at Military Hospitals and to visit the

hospitals periodically to see that the regulations were being carried out' [8]. His general recommendations, not restricted to military operators, were published as a broadsheet by the Röntgen Society in November [9]. (Figure 2)



RONTGEN SOCIETY.

Recommendations for the Protection of X-ray Operators.

The harmful effects produced by X-rays are cumulative and do not generally appear until some weeks or months after the damage has been done. It is to be noted that X-rays of any degree of hardness are capable of producing ill effects, although it is commonly supposed that soft rays only are harmful.

It is undesirable that any X-ray treatment should be carried out except under the direction of a qualified medical practitioner experienced in X-ray work.

All X-ray tubes must be provided, when in use, with a protecting shield or cover which prevents the access of rays to the operators and which encloses the tube, leaving an adjustable opening only sufficiently large to allow the passage of a sheaf of rays of the size necessary for the work in hand. Even with this shielding the operator may not be completely protected in all cases (*e.g.*, especially in screen work), and the use of movable screens, gloves and aprons is recommended.

Operators should be warned that shields obtainable commercially are often ineffective and tests of their opacity should be made.

Whenever possible the cubicle system should be used for X-ray treatment and the operator should be able to make all adjustments from a protected space.

When screen examination is required it is essential that the screen should be covered with thick lead glass of proved opacity and that the screen should be independently supported and not held in the hands of the operator. If the hands are so used they should be properly protected.

The hand or any portion of the body of the operator should never be used to test the hardness or quality of the X-ray tube; any simple form of penetrometer can be easily arranged for this purpose.

November 1915

Figure 2 Röntgen Society Recommendations for the protection of X-Ray operators. November 1915.

By this time the War Office had already decided that there was a need to add scientific expertise to Reid's undoubtedly competent clinical advice. A general call to academic science and engineering departments was being made, covering a wide range of technologies, to recruit bright young scientists to support the war effort, and it seems probable that it was such a call that resulted in the recruitment of the Frederick Harlow. He had graduated with a first from the Royal College of Science (later Imperial College) in 1908, and had secured a post as physics lecturer in the Sir John Cass Technical Institute. Since then he had published papers on several topics in physics, although only one, on 'Ionisation by collision' was relevant to x-rays. At the end of April 1915, Harlow was 'appointed to assist in the supervision of the output and the installation of X-Ray outfits for the British Military Hospitals' [10]. The post became full-time in August when Harlow was 'drafted into the War Office to take charge of the X-Ray work', given temporary unpaid leave of absence from the Cass Institute to do so [11].

Staffing

It was one thing to purchase and install the equipment and make it safe to use, quite another to operate it competently. Recognising the urgency in staffing, the War Office filled the gap with physics students. They were placed in war hospitals and instructed for a week by the resident radiologist, after which they would be passed as suitable to operate the equipment. Not surprisingly, this training and recruitment process came in for much criticism [2]. As we shall see, it was only later in the war that more robust training for radiographers was set up. Meanwhile, there were many instances when people with little or no knowledge of radiography were left to operate an X-ray set. In one case a chaplain who had dabbled in ham radio before the war was trained one day and took over single-handedly the next [12]. Some who offered help were more appropriate. The Hon Robert Strutt, (later the 4th Lord Rayleigh), Professor of Physics at Imperial College, acted as the radiographer at No 25 General Hospital in Calais during his summer vacation in 1915.

The War Office also advertised for military radiographers. The salary, £200 p.a., reflected the technical skills required. The candidate firstly needed to have 'a complete knowledge of X Ray apparatus and be competent to locate faults therein and carry out minor repairs'. Whilst 'a good knowledge of anatomy' was also required, this was not a priority and there was no expectation of clinical experience or competence. Neither was there any mention of photographic processing. It was assumed that there were plenty of other RAMC staff members who knew a great deal about anatomy, and that there would be orderlies who had done a bit of photography before the war. What was missing was the technical knowledge needed to manage the x-ray equipment.

The X-ray Committee is proposed.

Harlow was proving to be a valuable and keen technical advisor, but he had no background in medical radiology. Charles Phillips, on the other hand, was a very senior and experienced radiological physicist. He later commented only that 'It was then decided to form a War Office X-Ray Committee consisting originally of three people, Reid presiding.' Harlow was to be given the job as secretary. The evidence points to Phillips as the prime mover. According to him, Reid was not really in favour of committees. For himself, Phillips brought another essential skill to the enterprise, a good understanding of military organisation, gained from his years as a captain in the Volunteer Reserve.

Reid and Phillips, although with different career paths, had some things in common. They were both in their early 40s and both were married. Notably, neither had gained a university degree, and the respected positions that they held in the radiological community had been earned by skill and hard work. Phillips had been a founder member of the Röntgen Society in 1897, having published the most complete bibliography of x-rays earlier that year. After mobilisation orders were issued on 4 August 1914, he had withdrawn from his position as honorary physicist at the Cancer Hospital to take up the post of Officer in Charge of the X-ray Department at the Royal Herbert Military Hospital in Woolwich, near his home on Shooters Hill.

The 'Proposal for the formation of a committee to control and supervise the X ray work under the direction of the War Office' was sent by Reid to the Army Medical Service, Branch 3, on 30 September 1915 [13]. Central to the proposal was the

establishment of an x-ray laboratory in the physics department at Imperial College, placed under the overall supervision of Hugh Callendar FRS, Professor of Physics. The selection of Imperial College could have been due to the influence of Alfred Keogh who, in addition to being the Director-General of the Army Medical Service was also the Rector of Imperial College. However it arose, military protocol allowed Reid to communicate directly with Callendar, whose name was added as a member X-Ray Committee. Callendar's name does not appear in the later Official Report, however, suggesting that his involvement did not extend far beyond a general supervisory role as head of department.

The physicist James Brinkworth was appointed to take charge of the laboratory, initially half time while he continued as a physics lecturer. Brinkworth had graduated from in 1906, immediately joining the academic staff. At the same time he started to teach physics to the first-year medical students at St Thomas's Hospital Medical School. As an established physics lecturer when Reid arrived in 1912, Brinkworth may well have helped Reid to develop his radiology department there. He was described as 'A stern man, a discerning man, with a considerable presence. When he spoke, you listened!' [14].

In addition to Brinkworth, the laboratory opened with two other members of staff. Another Mr. Phillips, probably the physicist Francis Phillips who had graduated from Imperial College in 1913, was employed half time for £2 per week. A full-time mechanic from the physics workshop was employed at a salary of £3 per week. The facilities of the Physics Department were made available at no cost, including the use of test equipment and space. The only other anticipated expenditure was the cost of materials for repairs, and laboratory tests. There was much emphasis on cost saving.
At the outset, the stated purpose of the test laboratory was:

1. 'The testing and examining all X-ray equipment supplied to the War Office, including coils, interrupters, tubes, intensifying screens and fluorescent screens.
2. 'Examining the apparatus made by various makers with a view to determining which firm is providing that most suitable for military work
3. 'Testing the generating sets bought by the War Office; also overhauling and, if considered advisable, putting in thorough repair the old Stewart-Turner engines.
4. 'Testing the protection afforded by the X-ray outfits ordered by the War Office.
5. 'Inspection of X-ray outfits at various hospitals.
6. 'Considerations of any new schemes or any new apparatus.'

Several of these objectives responded to known issues. The need to test adequacy of protection was now established, although the plan stopped short of remedial action. The principle of inspection visits had been established; the MRC had asked Sidney Russ to carry out tests in hospitals, and Charles Phillips had already carried out his first inspection visit in the summer. The War Office was well aware there was a problem with the generating sets that needed urgent attention.

But some of the objectives broke new ground, being more in line with the approach already in place for other items of medical equipment, for example for clinical

thermometers and surgical instruments. It was intended that the laboratory should type-test all component parts of every x-ray system and, moreover, carry out evaluations of complete systems from all potential manufacturers, standing in judgement as to those that would be suitable for purchase by the War Department. Furthermore, a development role was included, which would allow the laboratory to consider new schemes and new apparatus. It would not be until the National Health Service was established that any centrally-funded programme of evaluation, management and R&D for radiological equipment came close to this in scope and ambition. It could only have happened within an environment where large centralised decision-making was taking place.

One paragraph is revealing, exposing potential fault-lines in the Committee's early purpose and planning. This was a physicists' proposal and it was most probably initiated and drafted by Phillips and Harlow, even though it was Reid who sent it to Stanistreet. In only one place is the question raised of the clinical use of the equipment. Note 1b added:

> 'The testing of X Ray Outfits electrically, although enabling one to discover if the outfit is in satisfactory working order or not, is no criterion really as to whether the outfit is tuned to give good results radiographically. In fact it is quite possible for an outfit to behave extraordinarily well on the electrical test and yet to be quite inferior for practical work. It is therefore obviously necessary that the outfits should be tested from a radiographic point of view before any decision can be arrived at as to which manufacturer is supplying the most suitable apparatus.'

This note stopped just short of undermining the whole thrust of the proposal. Reid was the only doctor on the Committee at this stage, and this expressed his concern that an evaluation that did not include a clinical test would be of limited value. But it is significant that, although he was the chairman, he allowed the proposal to go forward without including any specific plan for clinical evaluation, for example testing resolution or penetration for particular clinical applications. It all points to Phillips as the main driving force. Only later would the radiologists' voice become stronger.

The War Office X-ray Committee started work on 6 December 1915. The Official History reports: 'At the end of 1915 a committee of experienced radiologists and physicists was formed, under the chairmanship of Lieut-Col Archibald D Reid, to assist the section of the Army Medical Supply Branch'. In reality, at this date, both Phillips and Reid both held only the relatively junior rank of Captain, Reid's a temporary rank in the RAMC, necessary for him to act within a military hospital, and Phillips because he had been in the Volunteer Reserve before the war. Their higher seniority came later. Furthermore, it would be some time before additional radiologists joined the Committee. They met weekly. The workload meant that Reid reduced his commitment to the 2nd London General Hospital and Russell Reynolds, recently returned from a military post in India, took over.

The Imperial College X-ray Laboratory

During the next year, progress was made on most of the objectives stated in the proposal. In December, James Brinkworth summarised the work of his laboratory in

Imperial College [15]. With less technical detail, a formal Committee report was prepared for the War Office [16].

Stewart-Turner Generators

The War Office was particularly anxious to deal with the endless complaints about the generators. The first X-ray Field Service Units sent to France were supplied with small Stewart-Turner motorcycle generators to recharge the lead-acid batteries powering the x-ray equipment. These caused problems from the outset, which resulted in much irritation in RAMC hospitals. In Boulogne the motorcycle engines were dispensed with entirely and the accumulator batteries were charged at a central location. Shrewdly, the proposal had recognised this problem and placed it as a priority, to be addressed as soon as the Imperial College laboratory opened. The full-time mechanic, Mr. White, had been employed specifically to trouble-shoot and repair these faulty engines, a part of the project that was expected to be completed in six months. By the end of 1916, seventeen damaged engines had been repaired and modified to work better. In due course they were progressively replaced by more powerful Austin engines, but even these was not fully satisfactory, a number being modified by adding extra insulation to the armature to prevent sparking.

Equipment evaluation

Over the lifetime of the project, a huge range of new x-ray systems and components arrived at the laboratory for evaluation and comparison. Several hundred tubes and valves were tested. Before the war, British manufacturers of x-ray tubes were almost entirely dependent on the supply of lead-free glass from Germany. When this dried up, it was necessary to import x-ray tubes from the USA, a situation which changed only slowly as the war developed. Even by 1917 only 40% of the tubes to army hospitals were British-made, once they had reached the standard of imported American tubes. Coils, interrupters and rectifiers were tested under laboratory conditions, monitoring performance using a tube 'oscilloscope' to check the reverse current, each coil operated under varying loads with each of several types of interrupter, mercury jet, dipping blade or electrolytic (Figure 3).

Figure 3 'Oscilloscope' patters from a variety of **coil**/current/rectifier combinations. I. Bad coil construction. II. Good coil at 5 mA. III. Good coil at 15 mA. IV. Heavy current . V. As IV with valve to limit reverse current, 18 mA. VI Single discharge at 30 mA with rectifying valve. Arthur and Muir 1917.

Couches were tested for their x-ray transmission loss. Photographic plates and papers and developing and fixing solutions were evaluated. The sensitivity, definition and grain of about four hundred intensifying screens were tested during the first year, and the widely varying performance was brought under control, although the efficiency was still not as great as that of German-made screens. Fluorescent screens were tested for definition, brightness and after-glow. They even received several radiotherapy units for evaluation.

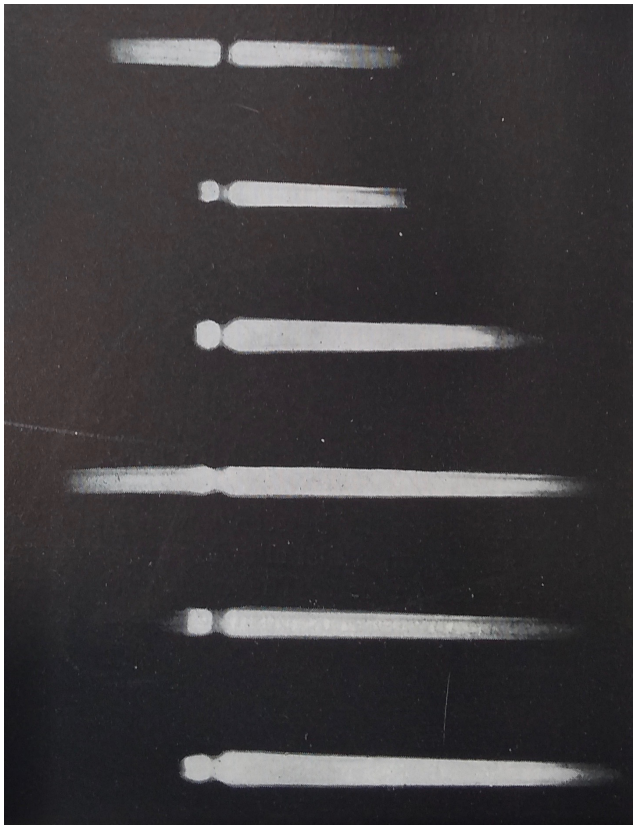


Figure 3 'Oscilloscope' patters from a variety of **coil**/current/rectifier combinations. I. Bad coil construction. II. Good coil at 5 mA. III. Good coil at 15 mA. IV. Heavy current. V. As IV with valve to limit reverse current, 18 mA. VI Single discharge at 30 mA with rectifying valve. Arthur and Muir 1917.

Specifications

Based on the results of the programme of tests, they developed specifications, including ones for fluorescent screens, couches, interrupters, meters and coils. Specification 2 was for x-ray tubes that were to be of the American Macalister-Wiggin design, forcing British manufacturers to slowly improve the standard of their products. In addition they developed specifications for complete systems, for fixed hospitals, for hospital ships, for field service units and for x-ray vans. However, their first priority was for radiation protection and Specification 1 was for lead rubber. They found that commercial gloves, aprons and lead glass varied widely in attenuation. Brinkhurst and his colleagues tested the x-ray attenuation of as many commercial samples as they could procure. A very simple performance criterion was established based on density, for which a minimum of 4.8 g cm^{-3} for lead rubber was set. This could be evaluated by weighing a known volume cut from the sheet. In addition, a limit on the conductivity of the material was set in order to prevent electrical discharge through it. Specification 3 set the minimum density of lead glass to be 3.8 g cm^{-3}, and a thickness of approximately 4 mm. Specification 4 gave the thicknesses of lead rubber used to line the x-ray boxes for both over-couch (4.2 mm all round) and under-couch tubes (5.2 mm for the top, otherwise 2.6 mm), for the attached aprons (1.6 mm) and for the leaves of the diaphragms (2 mm). These standards set much better protection than was common before the war, when even high quality units were often supplied with only 1 mm lead rubber protection for the undercouch tube. The thickness of lead rubber for aprons and gloves was also specified (1.6 mm).

Store, repair and disposal.

Charles Phillips had used the Army Medical Store in Woolwich as a store for surplus and faulty x-ray equipment from Military Hospitals. It is probable that this is where

the Field Service X-ray Unit was sent for testing, as requested by the Röntgen Society. Shortly after the laboratory was opened at Imperial College, space was released on an upper floor for a store and this allowed the equipment to be brought closer to the laboratory and workshop. A strict process was set up to decide whether it should be marked as 'serviceable', 'repairable', 'unserviceable' or 'for destruction'. Faulty equipment was repaired in the Imperial College workshops. Unserviceable equipment was dismantled for use as spares. The rest was scrapped, the laboratory acting as the 'Board of Final Adjudication'. By the end of 1916 a reserve of spares had been assembled, enough to last up to six months.

Inspection of x-ray departments

There was a consensus that inspections were essential and the new Committee structure allowed these to be carried out in a more formal way. Phillips had already carried out at least one inspection before the Committee had been formed, of a new department at Lewisham Military Hospital under the radiologist Dr James Herbert Rhodes. His report, dated 12 June 1915, encapsulates several of the problems encountered in these new military hospitals, often housed in buildings previously used as workhouses, colleges or schools. Phillips reports that the x-ray room is too small, the door is not wide enough to accept a bed, that there is no ventilation, and it is too far from both the operating room and the dark room. The equipment is designed to work from dc but the supply is ac. The wooden tube stand is unsafe, so it is only possible to work the equipment with an undercouch tube. One can only assume that Dr Rhodes was able to use this damning report to improve his facilities at Lewisham.

The Committee drafted terms of reference for any future inspections [17]. The first three objectives concerned protection and safety, to see that 'War Office instructions re protection are carried out'. The wording deliberately used the authority of the War Office to strengthen their authority. A specific request was made to 'enquire whether any injury from x-rays had occurred amongst staff'. The care and management of equipment and the suitability of the accommodation were to be investigated, as were the identification and correction of any wasteful procedures. There was, too, a recognition that everyone was learning. Objective 7 was 'to pass on useful devices and information and to co-ordinate the work of various departments'.

Phillips himself carried out the first inspection for the Committee. This was at Samuel Finzi's department at the 1st London General Hospital at St Gabriel's College, Lambeth, carried out on 31 December 1915. He found a spacious department, close to the operating theatre and darkroom, staffed by two enthusiastic radiographers and two orderlies. He was critical of the couch design, recommended that the coil be replaced with one more appropriate to the ac supply, and that the record keeping and plate storage should be improved. To begin with, the Committee restricted their inspections to only Military Hospitals in the London District, arguing that there were insufficient staff members available to go elsewhere. Nevertheless, they found out about all the other x-ray units in territorial, military and war hospitals [18]. The list included the hospital locations, the manufacturers of the installed x-ray apparatus and the names of the officers in charge (see Tables 2a-2g). It says a great deal for the status of the Committee that this information was made available to them. Three of those in charge were women, although only Florence Stoney was in a military hospital with RAMC staff.

They must have expanded the staff, because Phillips was already inspecting departments in the Eastern and Western Commands before the end of 1916, making visits to Brighton and Cardiff, and one with Archibald Reid to Aldershot. In each case the authority for the visit arose not from the Committee but from the Commanding Officer at the hospital. Nevertheless, there were many large war hospitals with x-ray departments that were not staffed by the RAMC, and the Committee was clear that they could not be held responsible for the quality or safety of the x-ray equipment used in them.

There were still insufficient staff members to allow every department to be regularly inspected. As a result they suggested that 'experienced medical officers or physicists who are already in charge of x-ray departments in hospitals under War Office control should be appointed to report to the X Ray Committee, and gain instruction as to the nature and scope of inspection required'. Army Form W 3462 was developed to allow inspections to be carried out by local staff, and the results reported back. Responses were required to questions about staff numbers, patient throughput, the type of electricity supply, the x-ray room design, the x-ray equipment and the dark room. Any recent changes in practice and equipment were assessed, including any additional protection that had been added since installation, and the proportion of cases that were screened. In delegating this role to a local officer, it is possible to see the first emergence of the relationship we see today between the Radiation Protection Advisor and Radiation Protection Supervisor.

Once the organisation for inspections of x-ray units in Britain was in place, the Committee started to consider units overseas. This resulted in a proposal that Major Higham Cooper, the radiologist in charge in Boulogne and Calais, should set up inspections, consolidate equipment depots and strengthen communication channels between France and London [19]. Cooper had been proactive in establishing his own workshop and it was proposed that this should be expanded so that defective equipment from all French RAMC hospitals could be sent to Boulogne in the first instance, and only sent on to England if repair was impossible. Red tape was minimised by allowing Cooper to communicate directly with the Committee through the Army Medical Department at the War Office.

Safety issues with the Field Service Unit

Sidney Russ's earlier initiative with the Röntgen Society on safety has been noted above. The Committee wrote a nine-point hazard notice, similar to that published in November 1915 by the Röntgen Society, and this was included in Harlow's illustrated 69-page War Office instructions sent out with every Field Service Unit [20].

Their advice warned that soft x-rays could cause malignant disease, and that harder x-rays could cause permanent sterility, both outcomes appearing at prolonged intervals after the initial exposure. It was advised to avoid exposure from the main beam, to use lead gloves and aprons at all times, to use film radiography rather than screening wherever possible, and to stand as far as possible from the tube. This advice shows an adequate appreciation of x-ray hazards as far as they were understood at the time, and gave some practical advice how operators might mitigate against the associated risks.

In February 1916, Charles Phillips attended a meeting of the Röntgen Society at which the safety of staff operating x-ray equipment in military hospitals was raised. Shortly afterwards, Russ wrote to Phillips reminding him of the 'growing body of

feeling on the subject of the protection of operators', and informing him of a further meeting in March when a resolution would be put 'to press upon the authorities the necessity for some scheme of inspection of the many Radiological Departments which have sprung into being recently'. At this meeting, led by Russ, a consensus emerged that a memorandum and resolution drawing attention to the dangers attending the present practice in Naval and Military Hospitals should be completed, and forwarded to 'the responsible authorities' [21].

Reid and Phillips drafted a carefully worded response to the Society's memorandum [22]. On several issues they were in agreement, and could report action. They agreed completely on the principle of systematic inspections of military x-ray units, pointing out that this was already being done. They assured the Society that that all gloves, aprons and lead glass were now being tested in the Imperial College laboratory and where inferior products were found they were being replaced.
The Committee went on to point out that the protection on equipment supplied to Military Hospitals had been identical to that supplied to civilian hospitals, so implying that the members of the Röntgen Society who were not involved in military radiology might wish to check the protection nearer to home. They were careful to omit any reference to the real problem – the Field Service Units. By now it had been realised that the first Field Service Units had been fitted with woefully inadequate protection, even by the standards of the time. One of the first actions of the Committee was to recall and retrofit improved protection for the undercouch tube on these units, which had been first issued with no protection at all on the upper side of the tube box, and quite possibly with no diaphragm either. During 1916, most of the poorly protected units were recalled, and a sheet of lead was added to the uppermost part of the box, surrounding an iris diaphragm. Two hinged protective flaps allowed the tube to be partially enclosed. Over the war years, several modifications were put in place for the Field Service Units, including the addition of rectangular diaphragm plates. [23].

Nevertheless, there is a sense that the Committee felt under attack and took a defensive position that, in retrospect, was not appropriate. Dr W Harwood Nutt, the Sheffield radiologist who was working at the Wharncliffe War Hospital, had reported to the Röntgen Society that 'operators who have been at work in France have returned to this country after three or four months with very bad ulcers and dermatitis on their arms and hands.' This was a serious assertion that needed a reply. Phillips and Reid responded by saying that the War Office had issued instructions and, if these were followed, no burns would be received. They added that no evidence of burns had been brought to their attention. Whilst they accepted that early equipment may have been supplied with inadequate protection, additional protection had now been mostly provided. This improvement, they maintained, was needed 'more from the fact that permanent sterility may be caused'.

It was an attempt at damage limitation, and they probably knew it. It was well known before the war that some x-ray operators working in civilian hospitals had developed dermatitis and skin cancer. Lazarus Barlow, Russ's head of department in the Cancer Research Department at the Middlesex, had stated unequivocally in his 1909 Croonian lecture 'the undoubted fact that workers with x-rays are liable to suffer from carcinoma of the hand'. Russ's colleague Reginald Mann died from disseminated cancer later in 1916. To claim that 'no evidence of burns had been brought to their attention' was at least disingenuous and at worst quite misleading. They knew by now

that the first Field Service Units had been issued with little or no protection, and were in the process of carrying out partial retrofitting of lead rubber on the under-couch tube boxes. The redirection of concern away from hand protection towards gonad protection missed the point. This last somewhat contentious assertion was deleted when the War Office drafted its official reply to the Röntgen Society, but it suggests that the protection being added was designed more for the pelvic region than to limit exposure of the face and hands of operators.

The reply sent to the Röntgen Society on 8 May was signed by Alfred Keogh, the Director-General of the Army Medical Service, indicating the importance of this issue to the War Office. The resolution and memorandum was placed before the annual meeting of the Röntgen Society in October 1916 at which the replies from the Admiralty and the War Office were noted. A short summary recorded 'that all possible precautions were carried out and that all installations were in the hands of experienced radiologists', a bland political outcome that ruffled no feathers [24,25].

It was the radiologists' hands that were the problem, of course. Screening, cautioned against in the Committee's advice, became more and more common as surgeons demanded quick diagnoses, military radiology became more widely used and casualties mounted. With tragic irony, Archibald Reid himself, so certain early in 1916 that no effects had been reported, would develop skin cancer, dying of its metastatic spread at the age of 52 in 1924.

It is difficult to fully absolve Archibald Reid, the War Office and Fred Butt of their individual and group responsibility for sending out Field Service Units with inadequate protection at beginning of the war. Certainly a quick decision was required at the time, and the design was a good overall practical solution to an immediate need. No doubt, too, finance was also a factor. X-ray equipment was a new and expensive addition to the Army medical budget, and every effort would have been made to reduce its cost to a minimum. In spite of clear evidence of the risks of x-ray exposure, there were many greater hazards during wartime. And many practicing radiologists, possibly including Reid, continued to believe that it was sufficient protection to follow simple rules of behaviour when carrying out radiological procedures, and that equipment design was of secondary importance. Nevertheless, the outcome was that, before the Committee and its laboratory started to work, many army radiographers had already been exposed unnecessarily to high levels of radiation and it took some time to bring the field x-ray units up to an adequate level of protection.

Working together

As had been anticipated in the original proposal, the Committee became a clearing house for information and advice. The physicist Edith Stoney, on leave in England during the autumn of 1916, met Reid and Phillips to talk about openings for military radiographers abroad. They were able to initiate an invitation from the War Office to explore a post for her in a Military Hospital in Salonika [26]. In return they would have wanted information about her experiences with the Scottish Women's Hospitals Units in France and Serbia. She was convinced of the need for rugged mobile x-ray vans to support remote hospitals in Serbia, a more urgent need than that in France. The first mobile units were sent to Salonika the following year. She may also have told them how she had imaged interstitial gas in casualties with gas gangrene in France in the autumn of 1915. In December 1916, Martin Berry, the radiologist

working with Phillips at the Royal Herbert Military Hospital, was able to present his own results [27].

A matter arose at the end of 1916 that could have caused conflict if Reid and Phillips had not respected one another's roles. Reid was upgraded from captain to major and Phillips was not. Reid was sensitive to this apparent alteration in hierarchy, adding a note to his 1916 Christmas card to Phillips and his wife. After expressing his pleasure at having worked together, Reid added 'I feel so disgusted that it has not up to now been possible to affect a change in the conditions under which you are working with regard to pay or rank. It really is iniquitous and if anything can be done to alter it, it shall be done' [28]. This was not in Reid's gift, however, and when finally Phillips was given the rank of Major in 1919, it was largely cosmetic now that the war was over. The differential was maintained with Reid becoming Lieutenant Colonel.
Reid and Phillips brought their own distinct views on the operation of the committee, and a brief note amongst Phillips' papers suggests that he took a more rigorous view than Reid did. Before the Committee was formed and Phillips had become a member, Reid had acted as an independent advisor, free to make individual decisions. It seems that it was in this spirit that he had been approached by Sir James Mackenzie Davidson with an offer to instruct radiologists in the London District in localizing foreign bodies in the eye, a technique on which he was the acknowledged expert. Phillips was clear that this matter should first come through the Committee, and noted 'Spoke Cpt Reid 20.7.16 & explained to him that the WO X-Ray Committee are the expert advisors to the WO in all X Ray matters & any proposals or suggestions Sir JMD may put forward will be submitted to the X-ray Committee for decision. ' There was, of course, no dissention and, on 25 July, he was appointed, although Phillips also made a note to himself that 'the D.G. informed him in an interview on the subject that the W.O. X-Ray Committee dealt with all matters connected with apparatus and equipment [29].

Radiologists join the Committee
Not long after the Committee was established, critical voices were raised from the wider community of radiologists, some of whom felt excluded from any influence they might have wished to exert on the War Office. Thurstan Holland wrote that Reid had only been 'helped by certain physicists' and 'that the expert radiologists of this country, as far as giving advice and helping to organize and control x-ray work, were entirely ignored' [4]. He believed that it was only through the sympathy of Sir John Goodwin when he took over as Director of the General Medical Services in 1918 that a change in the status of radiology in the War Office was initiated and that it was 'well into 1918 before any of them became effectual'. It was a view that represented a more general opinion amongst some radiologists and, by 1917, it needed a response.

As a result of this pressure, Reid added several radiologist members to his Committee. John Muir had been a general practitioner with radiology experience before the war and, in 1908, had published his *'Manual of Practical X-ray Work'* jointly with the therapeutic radiologist David Arthur, a book aimed primarily at Army and Navy surgeons in training. At the beginning of the war, Muir had been commissioned into the RAMC but had to return from France in 1916 as a result of injuries sustained in an accident. G. Harrison Orton from St Mary's also joined the Committee. William Hope Fowler from Edinburgh was co-opted. He was the radiology advisor to the Admiralty,

the parallel post to Reid's in the Army, in which capacity he would have agreed the design of the x-ray equipment that was installed in the Navy's hospital ships.

Localisation

In Muir's view, the radiologist's work was 'necessarily and entirely accessory to the work of the surgeon'. For Muir, who joined the Committee some time in 1917, localisation was its sole *raison d'être.* He even described the Committee as being 'specially appointed by the War Office to report upon methods of localisation of foreign bodies' [30]. His opinion was that surgeons preferred to use anatomical landmarks, and so he recommended that any method of depth calculation should always be used in conjunction with a stereoscopic view, the combination he claimed to be sufficient in 90% of cases.

At the start of the war, a very large number of approaches to localisation were already in use, and the matter had been an issue that the Committee had already addressed [31]. To begin with, their advice had been quite general. A single view x-ray image should never be used for localisation. Bi-plane radiography should not be used as the sole guide for operation, except in some cases when the foreign body was embedded in bone. The standard method to be taught to x-ray operators was to be the triangulation method, taking two views where the tube was moved laterally by a known distance, and the depth of the object predicted from the translation of its shadow. The question they had then addressed was this: given the general inexperience of the operators, which of the available techniques for calculating depth would be the simplest to introduce into a wartime situation? They selected one that had been developed by the radiologist William Hampson before the war [32] . By limiting the variables, fixing either or both of the tube-to-screen distance and the tube displacement, the estimated depth could be read directly from a simple scale. Instructions for this 'slide rule' method were written up by Harlow and circulated to every Field Service Unit, accompanied by a calibrated scale [33]. (Figure 4)

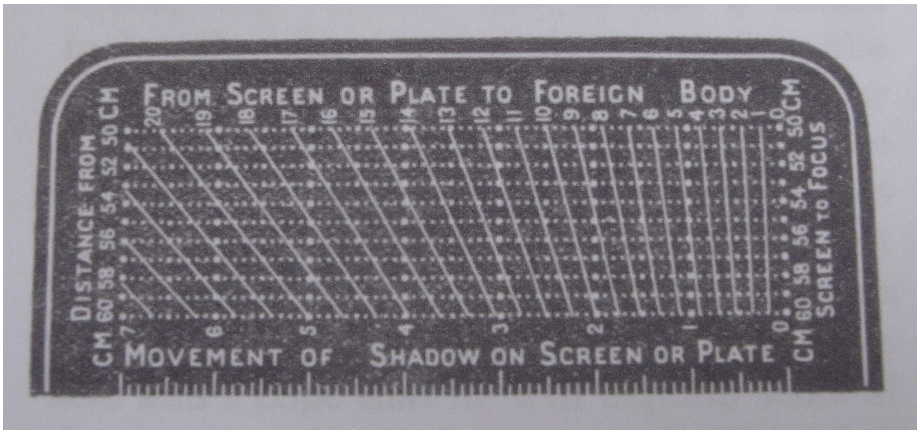


Figure 4 The Hampson calculator for localisation. The 'slide-rule localiser' recommended by the War Office X-ray Committee would have been very similar.

In due course the Committee came up with an alternative method. This simplified the measurement by using specially-designed pointers mounted on the under-couch tube box. Most importantly, the method placed a limitation on neither the height of the screen nor on the tube displacement. There was no claim to originality, the method being based on a technique described by Ombrédanne and Ledoux-Lebard in a text on

localisation for which Reid was the editor of the English edition. The two-pronged device, shown in figure 5, was bolted firmly to the tube box. In use, a lateral movement of the tube resulted in a means to calculate the depth that was independent of the height of the screen. The method was written up by Harlow and published under the name of the X-ray Committee [34].

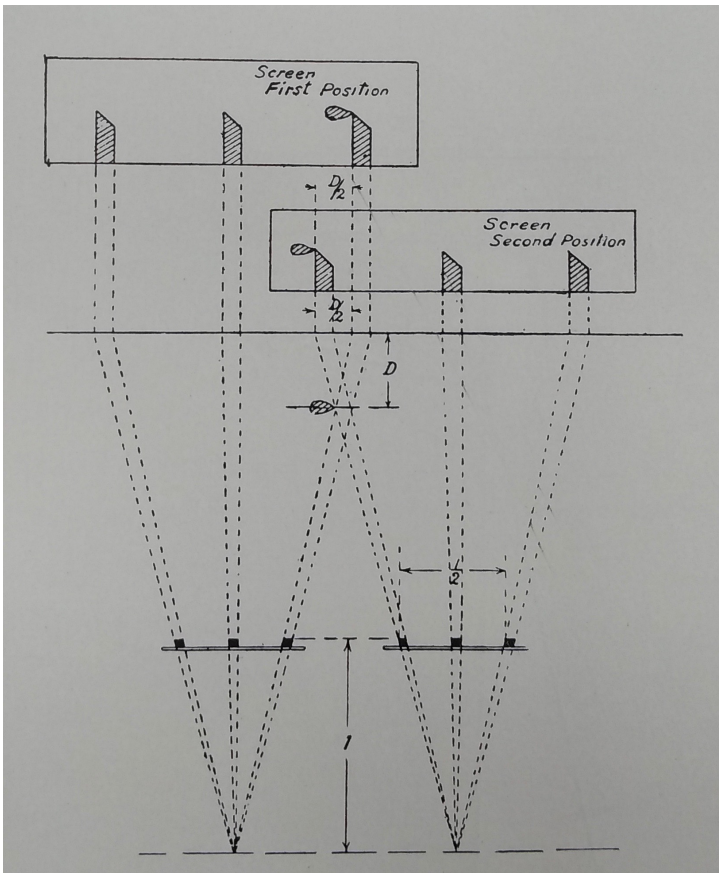


Figure 5 The War Office 'A.M.D. Grid Localizer'.

Training

Training was not within the Committee's initial remit, and there was no reference to training in the Committee's first annual report in December 1916. Nevertheless, they encouraged initiatives when they found them. In particular, they supported Cooper's arrangement in Boulogne by which Medical Officers should be given the opportunity for one month's x-ray experience on completing their tour of duty, in order to increase the potential pool of doctors with a knowledge of radiology.

But there was an evident and urgent need to set up a new training scheme for army radiographers. Before the war, trained nurses were given tuition in radiology by A J (Jack) Walton the army x-ray instructor at the Royal Army Medical College on Millbank [35]. Not only did this training scheme falter when Walton was drafted to France, it placed no emphasis on the necessary skills of equipment management. There was nothing in Britain comparable to Marie Curie's school of radiography that she established at the Val-de-grace Military Hospital in Paris.

The pre-war scheme for training x-ray operatives was no longer fit for purpose, and a replacement was required. The War Office assigned this task to the X-ray Committee. The Official Report later stated that the Committee 'trained orderlies in practical radiology and in the care, use and repair of X-ray apparatus'. In order to plan and teach this new course, Reid called on Charles Phillips to look after the technology and

physics, and invited Russell Reynolds to teach clinical radiology. It is probable that the training took place in the Army Medical College, Millbank, with the well-stocked store at Imperial College making available enough equipment for practical training.

This training was not designed for RAMC medical staff. Those doctors who were practicing military radiology picked it up on the job, spending a short time with a more experience colleague before practicing on their own. This had resulted in a wide range of competence, a matter of some concern to the Committee, especially to the new members who were themselves experienced radiologists. The Committee therefore 'undertook during the later years of the war to grade officers of the RAMC in their knowledge of radiography'. There is no suggestion that the educational responsibility of the Committee extended to training doctors in radiology. Instead, the Committee took on the role of assessing each RAMC doctor who was working with x-rays, and of deciding on the ranking of each in the military hierarchy, a tacit acceptance that not all were as competent as they should have been.

Continued work at Imperial College

Meanwhile, the main work of the laboratory continued and grew. The laboratory and store eventually covered more than 10,000 sq. ft. By the end of the war the staff had increased to become 'an expert officer in charge, a lecturer in radiography, three physicists and nine others as electricians and for carpentry, storekeeping and other duties'.

By the end of the war, 528 military x-ray units had been installed at home and abroad. There were over 196 in military hospitals in Britain, and a further seventeen overseas. 187 Field Service Units were issued for use in France and elsewhere overseas. Fourteen x-ray ambulances had been commissioned. X-ray units were installed in thirty-four hospital ships. Most of the units purchased from 1916 onwards were tested in the x-ray laboratory at Imperial College before dispatch.

Table 3 summarises the distribution of these 528 units. It also shows the change in priorities as the war developed. During the last two years of the war, an extra ninety-six military hospitals were opened in Britain and equipped with x-ray departments. New portable systems for ward radiography were introduced (Figure 6). In France, where the main hospitals were now established, emphasis turned to the design of x-ray equipment for casualty clearing stations, and twenty were commissioned with appropriate generating sets. More particularly, over one hundred more Field Service Units were tested and dispatched, some for France and others for hospitals further afield. Specifications for many more components were drawn up and agreed by the Inter-Departmental Advisory Committee, and the list had reached forty-six items by the end of the war.

Figure 6 The Cavendish portable x-ray equipment 1917 ‘as supplied to the War Office’

One particular development, mobile x-ray vans, deserves special mention. In May 1916 the committee had been sent a report from Captain Longley concerning his experience with a mobile x-ray van in France [36]. This was probably one of the two first mobile x-ray vans that had been deployed in June 1915. Both experienced teething problems. The War Office intended to provide five more and the committee was asked to advise. This was a new challenge about which the Committee admitted that they had no first hand knowledge. The greatest problem had been with the electricity supply both from the Austin generator housed in the back of the van and the rechargeable batteries. The Committee’s suggested approach was to dispense with the separate generator and to drive the dynamo by a belt from the engine of the lorry, powering the x-ray set directly and not from the accumulator batteries. By the end of the war, fourteen x-ray vans had been deployed (Figure 7). The reliable provision of power remained the most difficult challenge. The final design, described in detail by Howard Head in 1918, had a 3 kW generator, chain-driven from the van engine. Electrical supply for the x-ray equipment could be switched between generator, accumulators or both [7].

Figure 7 Austin mobile x-ray van c. 1917, showing tent framework and side access to interior and dark room.

Gas discharge tubes continued to be used throughout the war, and continued to fail. Over four thousand replacement tubes were issued during these two final years of the war. At the same time, hot cathode Coolidge tubes were introduced, even supplied for the later mobile x-ray vans. Whilst there was still caution that the Coolidge tube could not yet achieve the resolution of the old gas tubes, the advantages of stability and increased intensity were deemed to be sufficient compensation.
During this last phase, the laboratory expanded its testing to include electro-medical equipment. This was a logical extension from the testing of x-ray equipment at a time when joint departments of radiology and medical electricity were common. Furthermore, much of the emphasis in military and army hospitals had moved on to rehabilitation, for which therapy using heat, light and electricity played a large part.

Closure

In January 1919, the x-ray laboratory was moved out of Imperial College and housed temporarily in space on the 2nd London General Hospital site in Hortensia Road. In July it was split into a test laboratory, which finished up at the National Physical Laboratory, and a store that probably returned to Woolwich, from where inspections of x-ray departments in military hospitals continued for a few years [37]. The Governors of Imperial College received a letter from the War Office expressing 'the Army Council's most grateful thanks for the facilities afforded during the war in the Physics Department in connection with x-ray and electromedical equipment' [38]. The Governors' report added that the work had 'contributed very largely to the production of apparatus specially suited to war requirements'.

Reid and Harlow both left as soon as the laboratory was disbanded. Harlow initially returned to the Sir John Cass Institute as Head of Physics and Mathematics where he was given leave to 'continue to serve in an honorary capacity on the War Office X-Ray and Electro-Medical Advisory Committee' [39] John Muir took Harlow's place as secretary. In the preface of the third edition of his book, Muir was careful to credit 'the collaboration of Sir Archibald Reid and Mr. F.J. Harlow, colleagues with me in

the War Office X-Ray Committee'[40]. A successor committee was established, known as the Army X-Ray Advisory Committee and later as the Inter-Services X-Ray Advisory Committee, presided over by the consulting surgeon to the army. Phillips and Muir transferred to the new Committee, Phillips remaining until it was finally disbanded in 1939, and Muir probably replaced by the Army radiologist DB McGrigor in 1927.

One letter amongst Charles Phillips' papers casts a little light on the negotiations during this transition [41]. On 8 November 1918, Philips replied to a letter from Archibald Reid about his intention to step down as chairman. He had suggested that the X-ray Committee would probably take the view that the new chair must be an officer of the RAMC, perhaps John Muir, so excluding Phillips. Phillips replied: 'If therefore it is proposed to offer me any position of less responsibility and control than that which I now occupy …. I should feel forced to resign. ' He goes on to say:

> 'I am particularly sorry to have to take this line where Muir's name is mentioned because there is no one I would rather work with or under more than him, but it would be difficult to explain why I was willing, when the necessity due to the war was removed, to occupy a subordinate post and out of fairness to myself I do not think that I should do so.'

The following note was added in April 1919 to the copy letter: 'This letter gave rise to a hurricane but on the whole I think it served its purpose', presumably anticipating the creation of the replacement Committee with its surgeon chairman.

The initiative to identify radiologists as a separate medical specialty took shape with the creation of the British Association of Radiology and Physiotherapy (BARP) in 1919. A number of the Committee were among the founding members, including Reid and Muir and, more surprisingly, Frederick Harlow, one of only three physicists to be adopted as honorary members [42] Notably, the names of Russell Reynolds and Charles Phillips are missing from the list of members. The fact that it was these two men who created the training course for x-ray operatives may have influenced their decision.

The technical syllabus developed for radiographer training by Phillips and Reynolds formed the basis of the syllabus and examination for membership of the Society of Radiographers when it was established in 1920 with Archibald Reid as its first President. By this time A J Walton had returned from France and was running the course once more. On Reid's advice, the SoR Council instructed the secretary, George Westlake, to write to Col Sir Edward Scott Worthington RAMC, wartime Deputy Assistant Director-General of the RAMC, to ask for the syllabus of the army courses in radiography and electrotherapy. Two special examinations for Society membership were set during the first year of the Society's operation, based on the radiographic part of the army syllabus. The subjects examined were elementary physics and chemistry, the principles of apparatus construction and technique, radiography, radiation therapy and radiographic anatomy [43]. Walton recalled that the revised syllabus he inherited included localisation, the petrol engine and rotary converters, all technical aspects that were central to the concerns of the Committee during the war [44].

Archibald Reid died in a Swiss clinic on 15 January 1924. By then, Frederick Harlow had moved north, first as Principal of Wigan Mining College and then of Blackburn College before eventually moving back to London to become Principal of Chelsea Polytechnic. Charles Phillips had returned to the Cancer Hospital as honorary physicist, where amongst other things he investigated the possible use of uranium for therapy. He was a founder member and for many years treasurer of the Institute of Physics. John Muir became radiologist to the Hackney and Bethnal Green Hospital and at University College Hospital. The young physicist at Imperial College, Francis Phillips, moved to Birmingham where he became the Radium Curator to the General Hospital in 1929. James Brinkworth stayed at Imperial College, being awarded an MSc in 1919 and gaining a DSc in 1930 for his work on the physics of water vapour. He was physics examiner for the DMR examination by the Royal Colleges of Physicians and of Surgeons and continued to lecture in physics at St Thomas's until 1952.

Secrecy surrounded the work of the Committee during the war. Even someone as senior as the physicist GWC Kaye, working at the National Physical Laboratory, did not know what was going on at Imperial College and observed, in 1918, that 'We are all awaiting the publicity which the X-Ray Committees of the War Office and the Department of Scientific and Industrial Research are doubtless seeking for the results of their various experimental enquiries.' This publicity never materialised. The paper records of the Committee were discarded or destroyed. An official record was published, smoothing all the details into a compact summary. And so, anticipating that his own personal records might constitute the only first-hand documentation of these times, Charles Phillips tucked his papers away in a file, only to be brought to light by chance one hundred years later.

Achievements

What did the War Office X-Ray Committee achieve? Charles Phillips attributed the revolution in military radiology that came about during the war to Archibald Reid and the War Office X-ray Committee [1]. Phillips remembered the pre-war '10-inch coil, toy interrupters, accumulators, wobbly tube stand, and other ancient relics long ago relegated to the background', all now replaced with 'up-to-date equipment'. Of course, these changes would have happened anyway, one way or another, without their help. A more legitimate claim on their behalf was to ensure the posting of 'a trained officer in charge with an adequate staff to help him'. One achievement of the Committee was certainly to set up the first British training scheme for technically competent radiographers, replacing the training of nurse assistants that was in place before the war.

Nevertheless, it would be wrong to suggest that Reid's role was to 'take charge of the x-ray work for the British forces at home and abroad', as suggested in his obituary in the British Medical Journal [45]. As this narrative has shown, the primary role for the Committee was to act for the War Office Supplies Department in the specification, procurement and management of equipment in departments of radiology and medical electricity. It came in for much criticism because the Committee made little or no impact on the clinical practice of military radiology. It is important therefore to distinguish what was actually achieved from the well-documented struggles by radiologists to gain status for their profession in the eyes of their medical peers.

So was anything achieved that would not have happened if Reid had remained alone as the radiological advisor to the War Office? The answer, as set out in detail in the article, is clearly affirmative. Most obviously, the creation of the large well-staffed centralised x-ray laboratory and equipment store at Imperial College introduced a new professional approach to the management of radiological equipment that swept away the largely parochial attitude that had been prevalent before the war. Military hierarchies and rules, with all their limitations, created an environment that accepted central control, with all its obvious benefits in efficiency and cost savings, standardisation and robust, knowledgeable service provision. Manufacturers' claims for performance were checked and challenged. Inadequate safety provision was discovered and corrected. One certain achievement was the protection of many military radiological staff from inadvertent over-exposure from equipment installed with inadequate protection.

Several other achievements were time-limited. The two recommendations for simple techniques for localisation were relevant only under wartime conditions with comparatively inexperienced staff. Reliable generators were largely irrelevant for post-war civilian practice using a mains electrical supply. Transformers replaced the coil and interrupter. Gas tubes were superseded as Coolidge tubes became widely accepted.

However, a new principle had been established. Standards for the design, performance and safety of radiological equipment had been published for the first time. From now on, any manufacturer who intended to sell x-ray equipment would have to conform to these standards, or fail to secure a contract. A central test laboratory confirmed conformance, and users could hold manufacturers to account for failure to comply. Once established, this principle has remained in place and is now supported by a raft of international and national manufacturing and safety standards for x-ray and other equipment for medical imaging.

The existence of the X-Ray Committee also focussed the debate on issues of safety and protection. The two-pronged approach, using rules for safe practice built around well-designed safe equipment, evolved during the war. It led directly to the creation, in 1920, of the British X-ray and Radium Protection Committee and its published recommendations. It is possibly in this matter of protection that we can see the greatest long-term legacy of the Committee. Whilst the Röntgen Society took a well-documented lead in giving advice, it was the tough standards and specifications that were established by the Committee that forced manufacturers to introduce protection measures that had previously been considered as optional.

In summary, the War Office X-Ray Committee, supported by its x-ray laboratory at Imperial College, was set up as a specific response to unique wartime circumstances. As in so many other areas in which new technologies altered the process of war during WWI, the widespread introduction of radiology into military hospitals added a new technological dimension to military medicine. Its impact, including the added cost of procurement, the need for service and maintenance, the requirement for technical staff and the appreciation of its added hazard in an already dangerous environment, had to be addressed with skill and competence. This article has attempted to record the substantial achievements of Archibald Reid, Charles Phillips and the other members of their team in responding to these challenges.

I wish to record my special thanks to Peter Fisher, Special Collections, London Metropolitan University, Anne Barrett, Archivist, Imperial College and Barry Jenkins, Librarian, Institute of Cancer Research for their generous help and advice.

Table 1. Manufacturers supplying equipment to Territorial, Military and Army Hospitals c 1916 [5]

Manufacturer	**Total**
Fredk R. Butt & Co Ltd	27
Newton & Wright	15
Medical Supply Association	10
Watson & Sons (Electromedical) Ltd	10
Cavendish Electrical Co Ltd	10
Harry W. Cox & Co Ltd	9
A. E. Dean & Co	7
Schall & Schall	7
Allis-Chalmers	3
Mottershead	2

Table 2 Radiologists and Military Hospitals c. 1916
Table 2a London

	Hospital	**Radiologist**
Territorial hospitals	1st London General Hospital, Camberwell	Capt N Samuel Finzi
	2nd London General Hospital, Chelsea	Capt Archibald D Reid
	3rd London General Hospital, Royal Victoria Patriotic Building Wansworth	Maj F Howard Humphris, Cap W Albert Bowie
	4th London General Hospital, King's College	Capt Robert Knox
	5th London General Hospital, St Thomas's	Capt Claude Gouldesborough
Hospitals	Queen Alexandra Military Hospital Millbank	A Henry, HH Pooley
	City of London Military Hospital, Homerton	Christopher Kempster
	Hampstead Military Hospital	Edward W H Shenton
	Bethnal Green Military Hospital	Gilbert Scott
	Lewisham Military Hospital	J Herbert Rhodes
	Fulham Military Hospital	Florence A Stoney
	Tooting Military Hospital	Russell J Reynolds
	Southwark Military Hospital	George B Batten
	Mile End Military Hospital	C Thatcher

Table 2b Eastern Command

Hospital	Officer in Charge, X-Ray Dept
Northampton War Hospital	Dr Eva Muriel White
Edmonton Military Hospital	Dr J Metcalf
Aylesbury Central Military Hospital	Lieut JS Part RAMC
County of Middlesex War Hospital	Mr. CP Griffiths
1st Eastern General Hospital, Cambridge	A trained sergeant RAMC T
Royal Herbert Hospital Woolwich	Capt Phillips in charge Dr HM Berry, assistant
War Hospital Croydon	Capt HJ Bramwell RAMC
City of London War Hospital Epsom	Dr Findlay, Dr Van Den Dungen
Brook War Hospital, Woolwich	Mr. Simpson
Moore Barracks Hospital, Shorncliffe	Capt WH Eager CAMC
Military Hospital Chorncliffe	Capt A St. Ralph CAMC
Colchester Military Hospital	Lieut WJ Hogg RAMC
Harwich Military Hospital	Mr. WJ Wiltshire
Norfolk War Hospital	Dr St. G Barnham Blackman
Lakenham Military Hospital	Dr Basil Nutman
Purfleet Military Hospital	Lt Col Forrest RAMC
2nd Eastern General Hospital Brighton	Maj Bailey RAMC T Capt WB Prowse RAMC T
Kitchener Hospital Brighton	Capt C Morton
Pavilion Military Hospital	Mr. AL Stent (CMP)
Graylingwell War Hospital Chichester	Dr Isobel A Tate
Central Hospital Fort Pitt, Chatham	Capt W Garton RAMC

Table 2c Aldershot Command

Hospital	Officer in Charge, X-Ray Dept
Cambridge Hospital	Capt P Hernaman Johnson RAMC
Connaught Hospital	Capt FS Hawkes RAMC
Frensham Hill Military Hospital	M Auguste Demblon
Bramshott Military Hospital	Mr. SV Dolby

Table 2d Northern Command

Hospital	Officer in Charge, X-ray Dept
1st Northern General Hospital Newcastle	Maj WD Arnison
2nd Northern General Hospital Leeds	Capt FJH Stansfield
3rd Northern General Hospital Sheffield	Maj AR Hallam
4th Northern General Hospital Lincoln	Maj CAC Shipman
5th Northern General Hospital Leicester	Mr. Jevons
Northumberland War Hospital	Dr TL Bunting
Wharncliffe War Hospital Sheffield	Cpt H Harwood Nutt
Stoke-on-Trent War Hospital	Dr List
Bagthorpe War Hospital Nottingham	Mr. FV Clements
East Leeds War Hospital	Capt LA Rowden
Bradford War Hospital	Dr W Mitchell
Halifax War Hospital	Mr. A Haigh
Huddersfield War Hospital	Dr TH Edwards

Grantham Military Hospital	Mr. A Kingaby
York Military Hospital	Mr. HP Chapman Mr. WC Brain

Table 2e Southern Command

Hospital	**Officer in Charge, X-ray Dept**
Brokenhurst	Lieut FR Snell RAMC
Mont Dore	Capt SHE Oakeley SAMC
Cosham	Mr. Worsnop
Hursley Park	Maj AH Vernon RAMC T
Fovant	Capt JR Hall Walker RAMC
Codford	Lieut AL Saunders RAMC
Tidworth	Lieut CH Verge RAMC
Reading War Hospital	Capt WJ Foster RAMC T
Netley	Capt WM Howells RAMC
1st Birmingham War Hospital	Dr F Emerys Jones
2nd Birmingham War Hospital	Dr H Black
University War Hospital Southampton	Maj NE Aldridge RAMC T
Falmouth	Capt A Gregor RAMC T
1st Southern General Hospital Birmingham	Capt A Russell Green RAMC T
2nd Southern General Hospital Bristol	Capt J Taylor RAMC T
3rd Southern General Hospital Oxford	Capt RH Sankey RAMC T
4th Southern General Hospital Plymouth	Maj WC Wilson RAMC T Capt E Saunders RAMC T
5th Southern General Hospital Portsmouth	Capt H Lloyd Driver

Table 2f Irish Command

Hospital	**Officer in Charge, X-ray Dept**
Belfast Military Hospital	Civil Surgeon SW Allworthy
Cork Military Hospital	Capt F Bruce RAMC
King George Fifth Hospital Dublin	Civil Surgeon H Mason
Curragh Military Hospital	Mr. G Strickland

Table 3 Total military X-ray installations during WWI. Up to 1916, and from 1917 to 1919. 'Other abroad' includes the Mediterranean bases, Egypt, Mesopotamia and India together with a few other hospitals elsewhere.

	Home		**France**		**Other abroad**	
	1914 to 1916	**1917 to 1919**	**1914 to 1916**	**1917 to 1919**	**1914 to 1916**	**1917 to 1919**
Hospital	100	96	5	0	11	1
Field Service Unit with generating set	0	0	37	60	48	42
Casualty Clearing Station	0	0	0	20	0	0
Mobile on 3-ton chassis	0	0	6	2	0	6
Hospital Ship	0	0	0	0	32	2

Portable and trolley	2	57	0	0	1	0

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