The Invisible Light

The Journal
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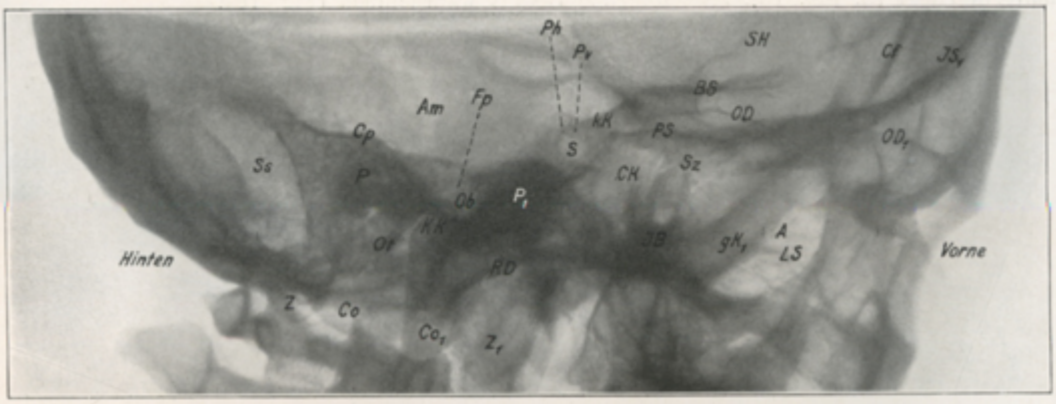

Fig. 17.

Skelett eines normalen Schädels; erste Aufnahme in gedrehter Position. 2/3 der natürl. Grösse.

A = Augenhöhle
Am = Furche der Arteria meningea media
BS = Boden der vorderen Schädelgrube
Cf = Crista frontalis
CK = Keilbeinkörper
Co = Condylus occipitalis
Co_1 = Condylus occipitalis der Gegenseite
Cp = Crista petrosa
Fp = Fissura petrooccipitalis
gK_1 = grosser Keilbeinflügel der Gegenseite
JB = Jochbein
JS = Innere Platte der Stirnbeinschuppe
kK = kleiner Keilbeinflügel
KK = Kieferköpfchen
LS = Siebbeinlabyrinth
Ob = Os basilare
OD = Orbitaldach
OD_1 = Orbitaldach der Gegenseite
Ot = Os tympanicum
P = Felsenbein
P_1 = Felsenbein der Gegenseite
Ph = Processus clinoideus posticus
Pv = Processus clinoideus anticus
PS = Planum sphenoidale
RD = Rachendach
S = Sella turcica
SH = Stirnhöhle
Ss = Sulcus sigmoideus
Sz = Sutura zygomatico-frontalis
Z = Processus mastoideus
Z_1 = Processus mastoideus der Gegenseite

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The Invisible Light (48)

Contents:

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Editorial.

This edition of The Invisible Light contains much of interest. Firstly, there is a review of a most interesting biography of Arthur Schüller the founder of Neuroradiology. On the front cover is a radiograph of the skull base annotated by Schüller in 1905. There are not enough radiological biographies and many more could and should be written. If anyone feels creative then might I suggest Valentine Mayneord (1902-1988) as a worthy subject? Val Mayneord was a remarkable man, and I met him several times. He would be worthy of a full biography.

Nicholas Taylor's article on X-Ray Processing is invaluable, particularly because he is giving an account of his own experience. Again, if anyone wishes to send me something about their own experiences then please get writing!

Frans W. Zonneveld and colleagues have written a masterly account of the early history of the early X-ray tubes, and this will become an invaluable reference. And finally, Dick Mould has written an important short account of Henry Snowden Ward, an important pioneer.

Please send me any comments and material.
Adrian

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New Book: **Arthur Schüller: Founder of Neuroradiology: A Life on Two Continents**. (2021) by John Keith Henderson & Michael A Henderson.
Hybrid Publishers (1 Feb. 2021) ISBN-10 : 1925736601 ISBN-13 : 978-1925736601
Thoughts by Adrian Thomas.

The most influential early figure in neuroradiology was Arthur Schüller (1874-1957)(1). Schüller practiced in Vienna and his famous book on the skull base was published in 1905 (2). The London neuroradiologist James Bull said that "without any shadow of doubt Arthur Schüller was the father of neuroradiology" (3), although perhaps we would now say originator or parent. Schüller described many of the classic plain film finding including pineal shift, cranial calcifications, and diseases of the pituitary fossa. He was also the first to describe the "map-like skull" in the syndrome called Hand-Schüller-Christian disease. His well-known textbook on neuroradiology was published in 1918 (4). He was forced by the political climate to leave Austria and between 1938 and 1939 briefly worked at the Nuffield Institute for Medical Research in Oxford, investigating the sub-arachnoid cisterns and their demonstration using a positive contrast agent. The Schüllers arrived in Australia late in 1939. it was difficult for the Schüllers to begin a new life in a strange land with a different culture. They settled in Melbourne and found a home in a suburb named, curiously, Heidelberg. Keith Henderson (1923-2017) was a neurosurgeon at St Vincent's Hospital in Melbourne and Erwin Schindler, Professor of Neuro-radiology at the University of Vienna Sadly the author John Keith Henderson did not live to see his book published, and Schindler had passed away some before. Schindler concentrating on Schüller's Viennese career and Henderson on his Melbourne years. Henderson has performed a good service to the radiological community by collecting all this material about Schüller. In particular the account of his work on the pituitary is interesting. It is difficult to find material about someone who died 64 years ago, and Henderson has done an excellent job in documenting both his private and personal lives. This book is warmly recommended.

Perhaps my main comment on this book is the poor quality of the images, which is unfortunate in a book about a radiologist. In this respect it is neither better nor worse than most modern books. The images in the hard copy are of low contrast and poor resolution. The text on the scanned images is difficult to read, and an interesting message from Walter Dandy to Schüller on page 73 cannot be read. On page 72 the images from *Die Schädelbasis im Röntgenbilde* cannot be seen well which is unfortunate since these are a major feature of he book. I was amused to read "shown are the front pages and a series of X rays reproduced as a photographic plate (printing was not up to the necessary resolution) with correlative diagrams." The images in the book are significantly worse than in the text of the 1905 book, although they are marginally better in the Kindle version. It may be that having better quality illustrations would have added significantly to the cost of the book, and the price is reasonable at £5.99 for the Kindle Edition and £10.99 for the hard copy (paperback).

Time is passing very fast; remembering may help against the uneasiness thereby evoked, remembering with gratitude (5).

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5. From "*En Recuerdo de Arthur Schüller*," presented by Erwin Schindler at the Seventh Congress of the Sociedad Iberolatinamericana de Neurorradiología Diagnóstica y Terapéutica, Buenos Aires, Argentina, November 1995.

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X-Ray Processing:
A Brief 'Personal' History and experiences as a Dark Room Technician

By Nicholas Taylor

The switch from analogue to digital permeates much of modern life and has provided numerous benefits, but there are costs associated with any change. There are the initial costs of the new technology, related support systems and training staff, and as the redundant technology is consigned to the recycling bin the knowledge and skills accumulated over years slowly disappears. Radiology is not exempt from these processes as it switched from chemical processing of films to Computed Radiography (CR) and Digital Radiography (DR), and the eventual loss of a once integral part of the radiology department, the Dark Room Technician.

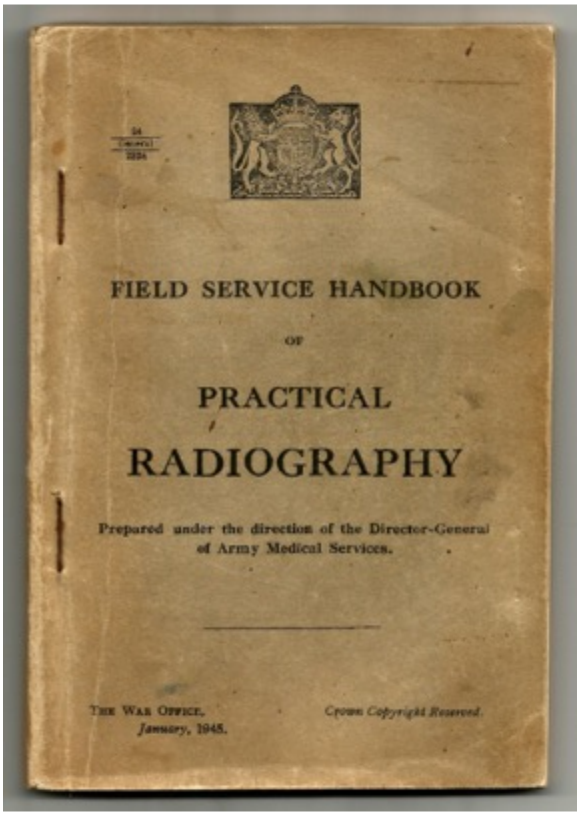
The Dark Room Technician's role involved maintaining the processing equipment and chemicals, Identifying, and resolving processing issues such as roller marks and film jams. Unloading, processing and reloading x-ray cassettes of various shapes and sizes. Using specific film types for duplicating or lightening an image, with the appropriate light filters, and not forgetting training radiographers to use the dark room facilities when the technicians were not present (and hopefully to avoid the film hoppers from having all their contents fogged when opened without the safe light on).

There has been much written about the history of radiography and processing systems, such as the article published in Radiographics 1989 (1), 'Film Processing Systems for Medical Radiography: A Historical Review' which shows how the processing of radiographic images has evolved. When researching the history of the dark room technician the number of results from a basic search of the internet is very low and the earliest reference the author has found to date specifically for a radiology dark room technician is an account published in *The Invisible Light* 2001 (2). of Noreen Chesney working 'in paid employment as a dark room technician' in a diagnostic X-ray department in November 1941

From a personal perspective I have been involved with processing radiographic images from 1985 while working in the veterinary profession. In 1988 I spent a year as a radiology department's dark room technician with the NHS before returning to the veterinary profession until 2002 when I enrolled with Cranfield University to study diagnostic radiography, revisiting much of the equipment I had previously used back in 1988. This has provided over 30 years direct experience of processing techniques from its most basic form to state of the art digital imaging.

The Basics.
Dark room design and chemical processing technique has been around for many years and publications from the 1940's such as 'The Physical Foundations of Radiology' (3), and the 'Field Service Handbook of Practical Radiography' (4), (Figure 1), detail basic principles which still apply, albeit in a more refined fashion today.

Figure1: Field Service Handbook of Practical Radiography published January 1945.



My first experience of processing radiographs was as basic as you could get, developing trays with chemicals stored in demijohn jars warmed up under hot water taps while watching a thermometer until the desired temperature was reached (or more frequently exceeded).

Radiographs were processed individually by hand under safe light conditions in developing trays. The amount of time in the tray varied according to the temperature of the chemicals, the warmer the solution the shorter the time required to process and if not watched closely would result in an over processed, dark image. The film would need to be agitated in the tray and when ready quickly rinsed before going into the fixer solution for a minimum of 30 seconds before it could be viewed briefly as a ‘wet film’ under normal lighting conditions before returning to the fixer and finally washed.

This method created a high number of variables in consistency of processing and image quality and was very user dependent. The film was also susceptible to damage while still wet when the emulsion could be scratched from the base layer and depending on the room temperature could take an hour or more to dry before being stored. Incorrect washing of the radiograph after immersion in the developer and fixer chemicals could later result in chemical smell and staining of the film.
The processing technique improved with the availability of thermostatically controlled processing equipment. The constant temperature of the water bath surrounding the developer, rinse, fixer provided improved image quality as the time required during each stage of the exposure process was less subject to variability. Films were also processed in channel or clips hangers which meant that more than one film at a time could be processed. Channel hangers helped prevent the radiographs from coming into direct contact with each other in the processing tanks,

but If films did stick to each other the result could be either an area on the film which could not be developed or fixed properly.

This processing method still had faults. The thermostat needed to be set at the right temperature ensure appropriate development. If chemical levels were not topped up then the top of the x-ray film would not be developed, (Figure 2,) and the chemicals could also become exhausted and contaminated, and, as I found on one occasion, if a film was left in the wash tank for too long the emulsion with the image could be completely washed off the base layer.

The films still needed to dry and this was either by air drying or using a warm air-drying cabinet. Films that left to dry in channel hangers regularly had marks on the emulsion layer which can be seen in Figure 2.

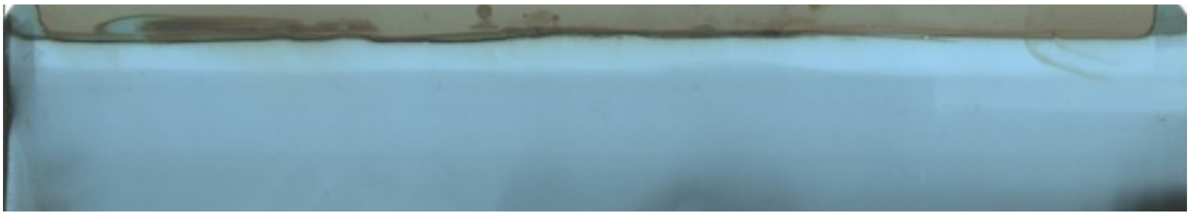


Figure 2: X-ray film showing undeveloped region at top due to incorrect chemical levels, and damage to emulsion layer on left side caused by a channel hanger.

Introduction of Automation.
The first prototype automatic film processor was introduced in 1942 and by 1965 was able to process X-rays in 90 seconds (1), but it wasn't until the mid 1980's that they were becoming more available and affordable for the veterinary market. The majority were intended to be used in dark rooms under safe light conditions, but others could be used without a dark room with light proof boxes mounted on the front with access ports for hands, (Figure 3). The x-ray film would be removed from the cassette within the box, fed into the film processor and the x-ray cassette reloaded with new film before being removed to be used again.

Figure 3: 'Daylight' Automatic processor. 1990.

The automatic processor provided repeatedly consistent development of the radiographs. The speed that the film traversed through the different stages of processing was controlled, as was the temperature of the chemicals which were automatically replenished with reserves held in tanks and films were completely dry at the end of the process, which only took on average a couple of minutes to complete.

Regular maintenance was essential with these units as chemical residue could build up on the internal components which could cause blockages to drainage holes. If the residue was on the transit mechanism marks could be generated on the film. The residue needed careful removal with a non-abrasive cleaner to avoid permanent damage to the transit mechanism which could cause even more marks on the film during processing. Most automatic processors fed the film through using rollers, but there were units which used a mesh screen which could often get damaged, fraying at the edges creating regular marking of the film.

The Radiology Department Dark Room Technician.
Veterinary radiology had become a catalyst for an interest in radiology, unfortunately a career path as a radiographer was not possible at this time but I did gain employment as a radiology department dark room technician at the Royal Devon and Exeter Hospital (Wonford). (Figure 4).

Figure 4: Royal Devon and Exeter Hospital (Wonford) 1988.

In the radiology department manual processing was generally the reserve of dental films which were too small to run through the automatic processors which handled all the other film formats ranging from 10x10cm, 35mm, 30x15cm OPT, 18x24cm, 24x30cm, 35x43cm, films to duplicate an image either as a straight copy, or to lighten an over exposed image to avoid the need for a repeat x-ray and single coated films with emulsion on one side in double sided cassettes used by the CT scanner to provide a hard copy of the image.

This particular department had three kodak automatic processors. Two attached directly to the dark room, providing a redundancy system if one processor was broken or being serviced / cleaned, and a third processor located in the viewing area attached to an autoloader which would unload, process, and reload cassettes. The processors were supplied with chemicals from a central source in the viewing area which was essentially a large vat about five feet in diameter, which when topped up took several 5 litre bottles of chemicals, a hosepipe for the water, and a mixing paddle on the end of a broom stick. Even in 2020 this would be a health and safety at work nightmare, (and this was before the Control of Substances Hazardous to Health, COSHH, came into force) as environmental exposure to chemicals used to process x-ray films could result in a number of symptoms collectively referred to as Darkroom Disease whose

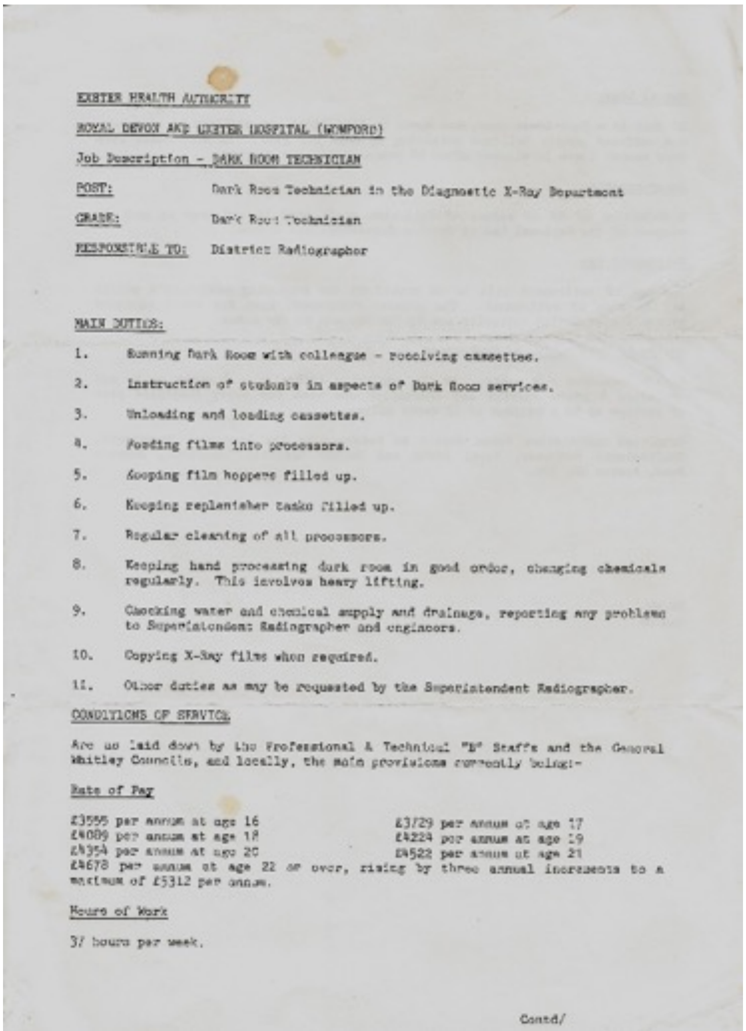
Symptoms include skin rashes, headache, blurred vision, palpitations, mouth sores (5), abnormal tiredness, itchy skin, shortness of breath (6). Dark room disease is still of concern in regions which still use chemical processing and (6).

The Dark Room Technicians ensured these processors kept running, the chemicals didn't run out, the film hoppers were full, the film had not passed its expiration date and new stock was replaced and ordered. They would also teach radiographers how to use the processing equipment and how to refill the autoloaders film hoppers, and at the appropriate time dealing with the silver reclamation from the waste chemical filters. Experienced dark room technicians could identify problems quickly and efficiently from sometimes subtle clues on a processed image, calculating at which point in the processing chain the problem originated. Film fogging was most likely to have occurred before the film was processed, the look, (and smell), of the processed film could indicate if the problem originated with the developer, fixer or wash process and a damp film may indicate a problem with the drying mechanism.

Depending on how busy the department, the dark room technician could spend most of their time in the dark room receiving x-ray cassettes through light proof hatches, putting the film into the automatic processor, reloading the cassette with new film, and placing it back into the hatch for the radiographers to use again. Sounds easy, now imagine doing it under safe light conditions with 2 or 3 hatches having cassettes slammed into them at the same time, (which in a small room is loud), someone knocking at the door as their film hasn't come out, or it's stuck to another film at which point the dark room technician would try to work miracles by rushing the films back into the dark room, separating them under safe light conditions and putting them back through the processors. This sometimes worked and the images on the films were saved.

Not all problems were caused by the hardware as there was still the human factor to contend with. Safelights are required to avoid accidental exposure of the unprocessed film to natural light, and the filter used was dependent on the sensitivity of the film. The safelights were activated by the dark room technician or radiographer when required, (thus allowing the dark room technician to exist in a state other than perpetual semi darkness). Film hoppers could accidentally be exposed to normal light unless they had an inbuilt switch to activate the safelight when opened, and film stock not in hoppers may have the lid left off their box after being used. There is nothing worse than finding that someone had left the film hopper open fogging the film stock, and having to do a systematic test from front to back to see how much could be salvaged.

Another problem could be the generation of static which would show on the processed image as fine black lines looking like lightning bolts, (Figure 6). A number of factors could cause this including environmental temperature and humidity, taking the film out of the cassette too quickly, or from some clothing. The latter resulted in a static discharge from my fingertips leaving a static representation of my fingerprint on a number of radiographs, which was often, unintentionally, over an area of interest on the image, usually a kidney.



EXETER HEALTH AUTHORITY

ROYAL DEVON AND EXETER HOSPITAL (WONFORD)

Job Description – DARK ROOM TECHNICIAN

POST: Dark Room Technician in the Diagnostic X-Ray Department

GRADE: Dark Room Technician

RESPONSIBLE TO: District Radiographer

MAIN DUTIES:

1. Running Dark Room with colleague – receiving cassettes.
2. Instruction of students in aspects of Dark Room services.
3. Unloading and loading cassettes.
4. Feeding films into processors.
5. Keeping film hoppers filled up.
6. Keeping replenisher tanks filled up.
7. Regular cleaning of all processors.
8. Keeping hand processing dark room in good order, changing chemicals regularly. This involves heavy lifting.
9. Checking water and chemical supply and drainage, reporting any problems to Superintendent Radiographer and engineers.
10. Copying X-Ray films when required.
11. Other duties as may be requested by the Superintendent Radiographer.

CONDITIONS OF SERVICE

Are as laid down by the Professional & Technical "B" Staffs and the General Whitley Councils, and locally, the main provisions currently being:-

Rate of Pay

£3555 per annum at age 16 £3729 per annum at age 17
£4089 per annum at age 18 £4224 per annum at age 19
£4354 per annum at age 20 £4522 per annum at age 21
£4678 per annum at age 22 or over, rising by three annual increments to a maximum of £5312 per annum.

Hours of Work

37 hours per week.

Contd/

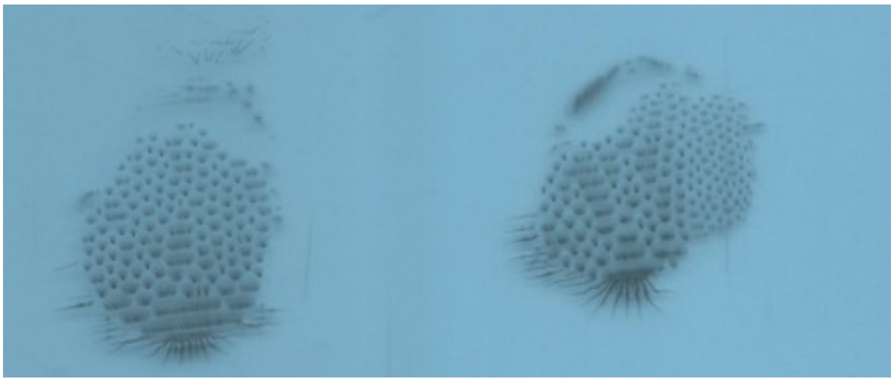
Figure 5: Dark Room Technician Job Description Jan 1988.

Another problem could be the generation of static which would show on the processed image as fine black lines looking like lightning bolts, (Figure 6). A number of factors could cause this including environmental temperature and humidity, taking the film out of the cassette too quickly, or from some clothing. The latter resulted in a static discharge from my fingertips leaving a static representation of my fingerprint on a number of radiographs, which was often, unintentionally, over an area of interest on the image, usually a kidney. The film stock also had to be protected from radiation sources as it would become fogged by scattered radiation so dark room construction, film and x-ray cassette storage had to provide an adequate level of protection.

The Digital Age.

Towards the end of the 90's chemical processing began to be replaced with Computed Radiography (CR) and Picture Archive Communication Systems (PACS). Software processes latent images captured on reusable imaging plates, which are then stored to a central database to be viewed on workstations across the hospital network removing the need for chemicals, their associated hazards and disposal requirements. The x-ray film can be viewed by multiple users across different work areas, simultaneously if required, and if required transferred electronically to other hospitals. Eventually the need for rooms filled with packets of x-ray films for each patient became unnecessary as subsequent imaging captured using CR is stored as data on a central server with backup systems.

Figure 6. Static generated from the authors fingertips.



Some hospitals switched completely to CR and PACS, while others had a phased introduction running chemical processing alongside CR. In hospitals with a phased introduction there was still a need for a dark room technician, whereas in hospitals which no longer used chemical processing, the job role evolved into Clinical Support Workers / Imaging Assistants, helping to prepare patients, and assisting the radiographers with clinical examinations as dictated by the needs of their respective radiology department.

Digital Radiography (DR) is replacing CR systems and becoming more affordable. Detectors are linked to the PC workstation either by a cable or by wireless image transmission and can produce an image 3 seconds. Processing algorithms are used (with caution) to enhance an image, and in conjunction with the development of artificial intelligence can aid detection of pathology. Their robustness is improving so that they are able to stand up to the demands of busy radiology departments and their weight reducing improving the manual handling issues of early designs.

For both CR and DR systems maintenance has become the remit of the service technician and faults may not be resolved on the same day especially if system hardware requires replacements parts. This does not negate the need for user involvement as data for retake analysis needs to be collected, and depending on initial system setup, may be an automatic process or require manual downloads. Databases also need to be set up and monitored as the local storage in the workstations can run out of space affecting performance.

Digital is replacing the chemical, and therefore the need for the skills and knowledge of dark room technicians. Although now a rarity in the UK, the radiology dark room technician is not an endangered species, (yet). Many countries across the globe still require chemical processing as CR and DR is not yet a viable alternative, but as the relentless technological switchover continues it will only be a matter of time.

I have been lucky enough to experience a wide and varied range of processing techniques but if I had to pick a favourite it would be right back at the very start, processing x-ray films by hand watching the image reveal itself in the tray before my eyes.

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Self-protecting X-ray tubes designed before Albert Bouwers' Metalix tube (1924)

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ABSTRACT:
This article describes the various attempts that were made in the early days of radiology to avoid the use of glass or to limit the solid angle of X-rays emitted from the tube before the introduction of a shielded metal X-ray tube (Metalix D) in 1924. The results are presented into five different classes depending on the type of shielding and the application and are based on a literature study.

INTRODUCTION:
In 1924 Albert Bouwers, who was working at the Philips Research Laboratory since 1920, introduced a unipolar X-ray tube partly made of chrome-iron and partly of glass, called the Metalix A [Fig. 1a][1,2] that was improved to the bipolar Metalix D

[Fig. 1b] in 1926. The chrome-iron outside shielded all X-rays, except for a small window that allowed the useful radiation to pass and, therefore, was coined a 'self-protecting tube'. This X-ray tube was such an innovation that, upon presenting it at the Radiological Society of America meeting in 1928, Bouwers was spontaneously honored with the RSNA Gold Medal .[3] Although he claims to be the first designer of a self-protecting X-ray tube[4], the question rises whether he really was the first and, if not, why the other designs are relatively unknown. Our research came up with five different classes of X-ray tubes that were self-protecting although not all of these had been designed with this purpose in mind:

A. Tubes made of metal designed with the objective to avoid the use of breakable glass.
B. Tubes made of metal designed with the objective to collimate the X-ray beam for laboratory experiments.
C. Medical tubes made primarily of lead glass, either for shielding purposes, or because soda glass was hardly available.
D. Glass tubes with internal shielding devices made of metal.
E. Medical tubes made, or partially made, of metal designed with the objective of radiation shielding.

X-ray tubes with an external form of shielding have been introduced very early and are not discussed in this article.[5]

1. Class A

The first tube in this class was designed by E.A. Woodward and was published on February 29th 1896.[6] This tube has a conical aluminum exterior with a thickness of 0.1 inch which is an anode at the same time (electrons impinge on the inside from a cathode that is placed in the center of the thick bottom glass base [Fig. 2][7], while the X-rays emit on the outside). The claim is made that this tube enabled taking a radiograph of the hand in 5 seconds.
A few months later, Benjamin Davies (1863-1957), who was working in the famous laboratory of Oliver Lodge, introduced his design.[8] It consisted of a metal tube with a thin aluminum half sphere at its end which acted as cathode with the anticathode in its center. The X-rays, emitted from the anticathode, were penetrating the cathode [Fig. 3]. Inside the cathode, behind the anticathode, there was a half metal sphere that acted as anode. It was reported that during fluoroscopy, at the distance of 9 meters from the tube, the bones of the hand were still discernible. A peculiar fact was that Davies applied mercury as a vacuum seal and porcelain as a high-tension isolator.
Around 1908, Frederick Alexander Lindemann (1886-1957), known for his lithium-beryllium-borate glass, allowing low-energetic X-rays to pass through, designed a metal X-ray tube as well [Fig. 4]. His design had a simple shape and did not use a transparent anode but a window that was transparent to X-rays.[9] He obtained a patent on his tube in 1908 and later on sold it to C.H.F. Müller. In the same reference[9], we also encountered a metal X-ray tube designed by the Italian radiologist Vittorio Maragliano (1878-1944) but were unable to find any further literature about it.

2. Class B

X-ray spectroscopy was the first new application of X-rays which Roentgen himself had not yet described in his publications. There have been a number of researchers who were active in this field and needed X-ray tubes that produced thin collimated X-ray beams to aim at the material to be investigated. The purpose, therefore, was not radiation shielding but collimation. These researchers were Manne Siegbahn (1886-1978)[10] in 1915, Peter Debije (1884-1966) and Paul Scherrer (1890-1969) in 1916, Assar Hadding[11] in 1930 and John Shearer (1865-1922) in 1922. In the last design, glass was used as isolating material. Due to lack of a good glass-metal sealing technique, wax was used as a sealing medium. Others used tar for this purpose. It is obvious that these sealing materials could only be used under laboratory conditions but not in X-ray tubes for medical purposes.

3. Class C

In 1902, the first (therapy) tube made of lead glass was designed by Alfred Charles Cossor (1862-1922) of the A.C. Cossor Company. He did not have radiation protection in mind but in England usually all glass items were made of lead glass as soda glass had to be imported from the European mainland. It was obvious that the radiation window had to be made of soda glass. This window was located at the end of a protuberance, and, therefore, the tube was also suitable for endotherapy.[12]
In 1905, Albert C. Geyser, a radiotherapist, who became specialized in permanent removal of undesired hair growth (hypertrichosis) by means of X-ray irradiation, designed a kind of therapy tube using lead glass for its exterior with radiation protection in mind. He named his tube the Cornell-tube[13] after his university. This tube was then incorporated in an apparatus (Tricho System) which he subsequently rented out to beauty parlors. Although he claimed his tube to be completely safe, in the end he lost both hands to the irradiation that occurred through the lead glass. Removal of hair by means of X-ray irradiation is being considered as one of the major medical X-ray catastrophes.
It is probable that Heinz Bauer (1879-1915) of the company Radiotechnische Werke Heinz Bauer in Berlin had radiation protection in mind when, around 1908, he designed the so-called Gamma-Röhre. This was an ion tube with an exterior made of 3 to 4 mm thick lead glass and a window of 0.1 to 0.15 mm thick soda glass. This tube was incorporated in the catalog of Reiniger, Gebbert & Schall of 1912.[14]
Finally, William David Coolidge (1873-1975), well-known for his hot-cathode so-called ‘Coolidge tube’, designed in 1920 a tube made of lead glass with a window of soda glass. Obviously, this was also a hot-cathode tube. Contrary to the previous tubes he placed his tube in an oil bath for extra high-tension shielding. This enabled a more compact tube design.[15]

4. Class D

As glass-metal connections were problematic in the first decades of the 20th century, many researchers chose for the option to place a metal radiation-limiting device inside of the glass X-ray tube.
In 1897, Max Levy (1869-1932), owner of an X-ray company in Berlin (Max Levy GmbH für Röntgengeräte), was the first to use this option [Fig. 5].[16] He had no radiation shielding in mind, but wanted to limit the primary X-ray beam to reduce the

amount of scattered radiation (the X-ray grid had not been invented yet) and thus avoid the veil of blackening on the film.
In 1898, the Frenchman Victor Chabaud (1860-1922) designed an ion X-ray tube, according to an idea of his colleague Paul Villard (1860-1934), with a conical radiation shield around the anode (both were made of platinum) named "anode à puit" [Fig. 6]. His purpose was to reduce the surface area of the anode producing the X-rays thus suppressing extrafocal radiation.[1] This tube is present in the collection of Zahi N. Hakim (www.earlytubes.com).[17]
In 1902 Friedrich Dessauer (1881-1963) [Fig. 7] had the same idea. He did not want to create an internal radiation shielding but to make a tube of which the hardness could be regulated and to use the internal shielding for better focusing of the electron beam on the anode by changing its charge by varying the anode current thus resulting in a better defined focal spot.[18] He also patented this idea.[19] Together with Emil Gundelach, the tube was produced and marketed as the Ideal-Röhre.
In 1915, William David Coolidge got the idea that his hot-cathode tube from 1913 could be supplied with a simple molybdenum hood being placed on the anode [Fig. 8].[20] On one side there was a little hole to let the electron beam pass and on the other side a hole to let the radiation pass. Later on, this kind of hood was often integrated with the anode design ('hooded anode') to increase the mass of the anode.

5. Class E

In 1914, Ludwig Albert Zehnder (1854-1949) had the idea to make an X-ray tube out of metal. Zehnder was a Swiss physicist who wanted to obtain his PhD at the institute of Hermann von Helmholz (1821-1894) but due to the lack of a secondary education diploma he was refused in 1887. During a walk in the mountains, he happened to meet W.C. Röntgen. Röntgen was well acquainted with the problems of a missing secondary education diploma and allowed Zehnder to obtain his PhD in his institute in Germany. Thereafter Zehnder became his assistant. In 1980 Zehnder obtained his Habilitation[2] and in 1893 he became extraordinary professor of physics in Freiburg, just in the period when Röntgen discovered the X-rays. In 1899 he became Röntgen's assistant for a second time and in 1900 he followed Röntgen to Munich. In 1904, Zehnder became a physics teacher in Berlin where he stayed until the outbreak of the first World War. At that very moment he was on holiday in his homeland and offered his services to the hospital in Zürich, as he had learned a lot about X-ray tubes in the meantime, and, on the occasion of an equipment breakdown, he was able to take action. He realized himself that the X-ray technology would be of help in the treatment of wounded war victims[21] but he was also disappointed by the fact that the X-rays had caused so many mutilations and radiation martyrs. These were caused by a lack of shielding and by the fact that often the hand was held in the X-rays as test object, to judge the hardness of the tube. He thus got the idea to design a tube with a metal exterior [Fig. 9][22]
William David Coolidge (1873-1975) read Zehnder's publication and his reaction was: "One could think of many reasons for Zehnder's tube to be unpractical, but, at least, he has defined the problem in a correct way. Such a metal tube would have great advantages if you could manufacture it at all."[23] As a result he made an attempt to build a metal X-ray tube himself [Fig. 10] and this, as he found out, was not easy at

[1] This is an idea that Bouwers also applied to his Metalix A tube in 1924 but which did not produce the desired result.
[2] Habilitation is a German prerequisite to obtain professorship.

all as he was unable to maintain the vacuum even if the tube remained on the vacuum pump. For some unknown reason the metal oxidized. Coolidge, therefore, filled the tube with pure hydrogen and heated it. Then the tube was pumped out and filled again with hydrogen. This cycle was repeated a couple of times and finally the vacuum remained. Another problem was that the glass often cracked in those places where the wire passed through the glass to connect to the cathode. He was able to solve this problem by placement of a metal shield to prevent heating. The experimental version of this tube had a very thin platinum anode such that the radiation was also emitted on the other side as where the electron beam impinged, but Coolidge mentioned that a version with an anode under 45 degrees and a radiation window would also be feasible. He imagined a cone-shaped metal diaphragm around the anode to let the desired radiation pass.

6. Discussion

Zehnder, Coolidge and Bouwers all designed a cylindrical tube (taking up less volume and therefore easier to shield) with an exterior partially made of metal. But where did their designs differ? First of all, the circumstances were different. Zehnder did not have access to a well-equipped laboratory or workshop but worked in a hospital in a neutral country during wartime. Nonetheless he was able to get assistance from the Polytechnic University (ETH) in Zürich. Coolidge and Bouwers did have access to well-equipped laboratories and also had a tube in mind that could be manufactured and marketed. In addition, there is a time difference of ten years between Zehnder and Bouwers and during that time two important developments took place. The first one was the hot cathode invented by Coolidge in a glass tube with a high vacuum. This resulted in the fact that the X-ray intensity (tube current) and the beam quality (high tension) could be regulated independent from one another. Ever since 1913 all tube designs were based on this concept; and Coolidge himself used it in his design as well. Bouwers also applied the hot-cathode concept. Zehnder still used the ion tube principle [Fig. 9]; with a charcoal regenerator, which he had constructed already a month after Röntgen's discover. The second development was the metal-glass connection. This was an invention by Gilles Holst (1886-1968) at Philips, who had noticed that the chrome-iron pipes of the glass blowers would nicely stick to the glass. He obtained the patent in 1922[24], and, as a result, Bouwers could make his tube partially of metal and partially of chrome-iron [Fig. 11] and sealed the tube after it had been evacuated. This novelty was not present in the metal tube designed by Coolidge and it was the main reason why Zehnder was not able to take his tube off the vacuum pump. Therefore, it is difficult to imagine how Zehnder envisioned using his tube under war conditions on the battlefield; combined with a vacuum pump? Finally, Zehnder, and we expect Coolidge as well, put the anode on zero potential and the cathode on full negative high tension. Bouwers did the opposite and put, in the Metalix A, the cathode on zero potential and the anode on full positive high tension. However, he discovered quickly that it would be better to isolate both cathode and anode and put them each on half of the high tension (bipolar mode) as subsequently in the Metalix D. If we follow the description by Zehnder[22], starting on page 828, we see that Zehnder had to use things that were available such as a porcelain isolator which he had to be connected to the metal part of the X-ray tube by means of sealing wax (this limited the temperature of the tube) while the metal parts were soldered together. The exit window was a convex piece of glass. Zehnder decided not to obtain a patent for his tube design. In January 1915 he went back to Berlin and, on the way, he visited Röntgen in Munich. While he was there a representative of an X-ray company[3], who was interested in his tube, approached him, especially because Zehnder had stated that the output of his tube would be a thousand times larger than that of an ordinary ion tube, which would enable cine-recordings. Max Levy-Dorn[26] has uttered his doubts about this statement as Zehnder had not proven it. In addition, he doubted whether the sealing wax was suitable to secure the vacuum. Martinus Eduard Goudsmit (1883-1942)[27] believes as well that Zehnder had presented a too rosy picture of his tube, and that he, instead of a thousand-fold output only a ten-fold output had proven. For Röntgen Zehnder had presented his tube design too early and the company representative had the problem that there was no patent. In the end Zehnder's tube was not taken into production and he mentions himself that Philips materialized his idea ten years later.[28] In turn, Bouwers was also aware of Zehnder's idea as he refers to it in his publications[1,2,29] but he considers it as an unpractical solution for special purposes. Bouwers does not mention Coolidge's metal tube, probably because it was not yet taken into production. In his RSNA-lecture in 1928, Bouwers refers to his own tube as "The first, and I may say the best known, self-protecting tube is the Metalix tube".[4]

7. Conclusions

In conclusion we may say that it is curious that Zehnder, in 1914, not had noticed that his colleagues in the field of X-ray spectroscopy, had already tackled the shielding problem. In addition, we can notice that Bouwers found himself in the fortunate position that the chrome iron-glass fusion technique was already available such that he was able to elegantly develop a self-protecting X-ray tube. Although the Siemens-Reiniger-Veifa Multix tube[30] came later (1929) on the market, it was known already in 1926 that this would happen. The tubes made of lead glass obviously did not provide sufficient protection and the other tubes were either the result of unique experiments or had a number of disadvantages that prevented them to be produced in large quantities.

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[3] This company must have been Reiniger, Gebbert & Schall because they claim that Zehnder granted them the manufacturing of his tube.[25] Siemens-Reiniger-Veifa finally put the Multix tube (with an exterior made of porcelain) in the market around 1929 but this tube looked more like Bouwers' tube.

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Figures.

1. The Metalix X-ray tube designed by Bouwers; partly made of metal for radiation shielding and partly made of glass for isolation of the high tension and for melting off the pump connection. 1 = chrome iron middle section of the tube exterior that has been fused to the glass, 2 = copper anode mass, 3 = cathode incandescent tungsten heating wire, 4 = glass part (green) of the tube exterior at the side of the anode, 5 = glass part (green) at the side of the cathode [in the Metalix A there is only one glass tube exterior and are 4 and 5 combined], 6 = anode pastille made of tungsten, 7 = lead radiation shielding, 8 = cap with additional radiation filter, 9 = exterior high tension isolation made of Pertinax (purple), 10 = container for cooling water, 11 = cathode connection, 12 = thin radiation window made of glass (green), 13 = tube hull made of chrome-plated bronze, 14 = supply tube for cooling water to the anode. Fig. 1a. Cross-sectional drawing of the unipolar (cathode is on zero potential) Metalix A (1924) according to Bouwers.[31] Fig. 1b. Cross-sectional drawing of the bipolar Metalix D (1926) according to Bouwers.[29]

Fig. 1a: The Metalix X-ray tube designed by Bouwers

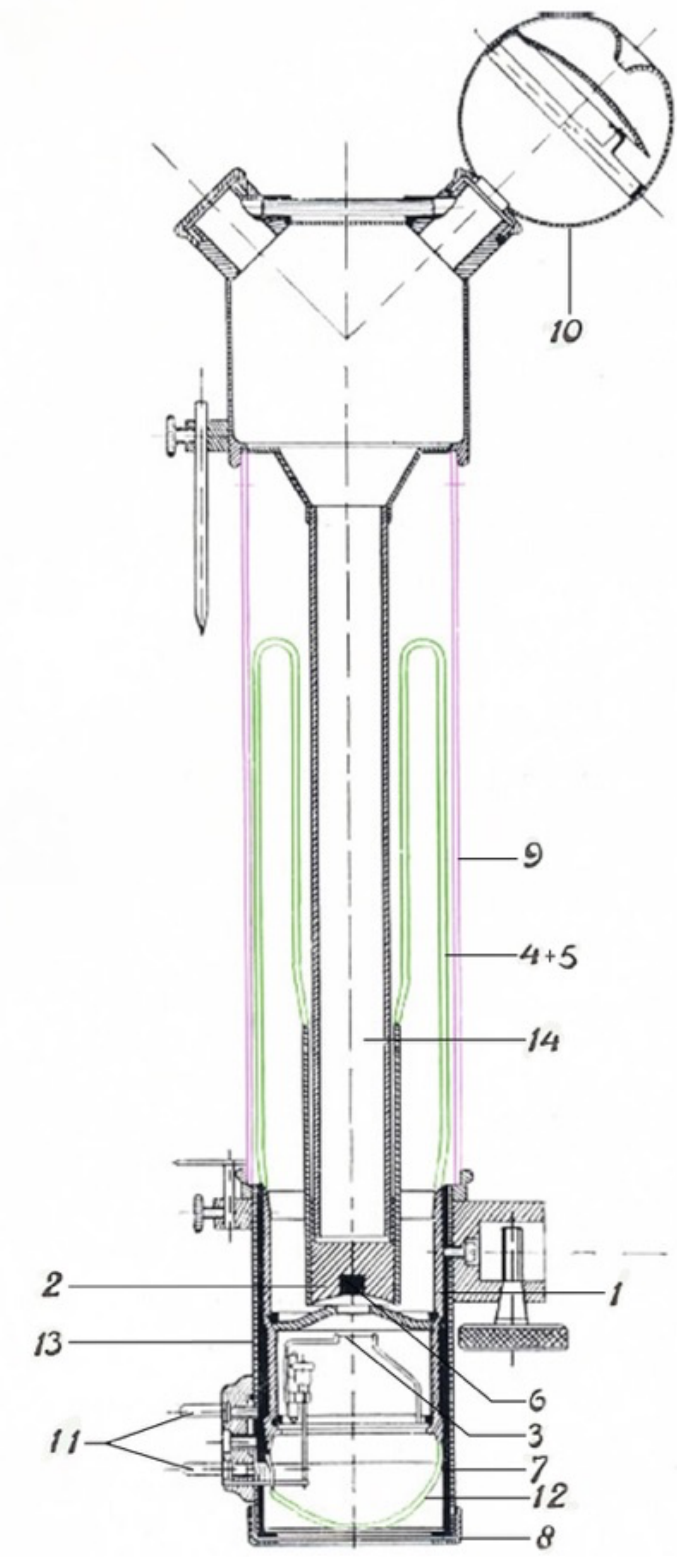
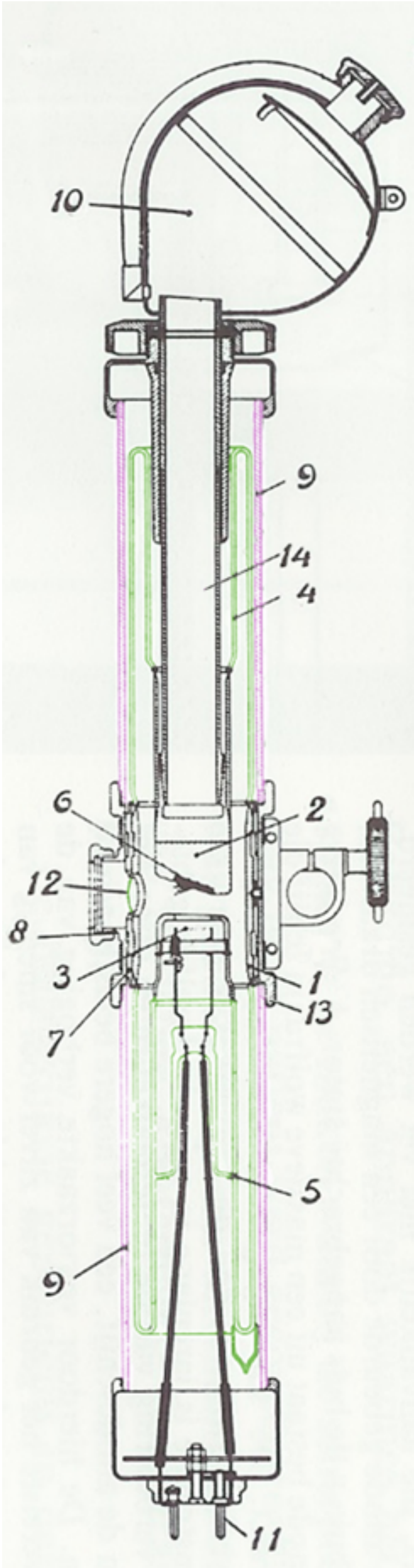
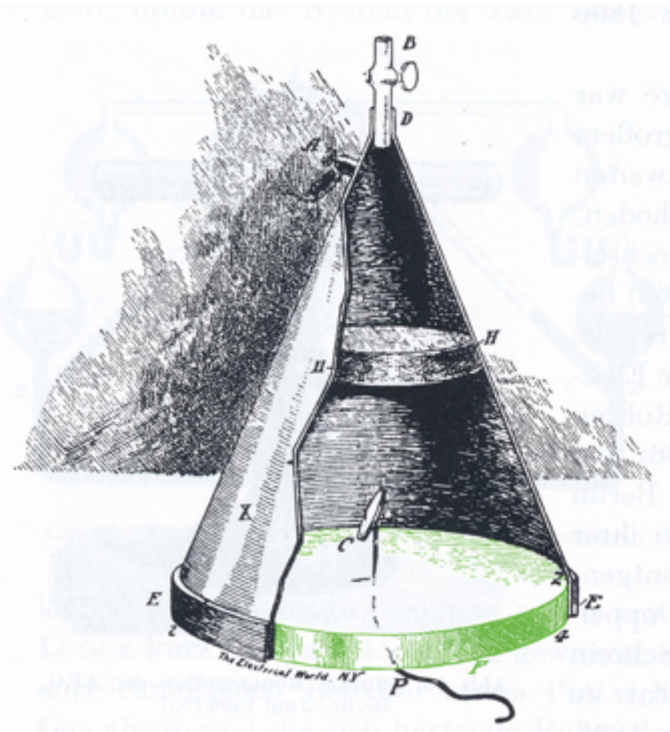


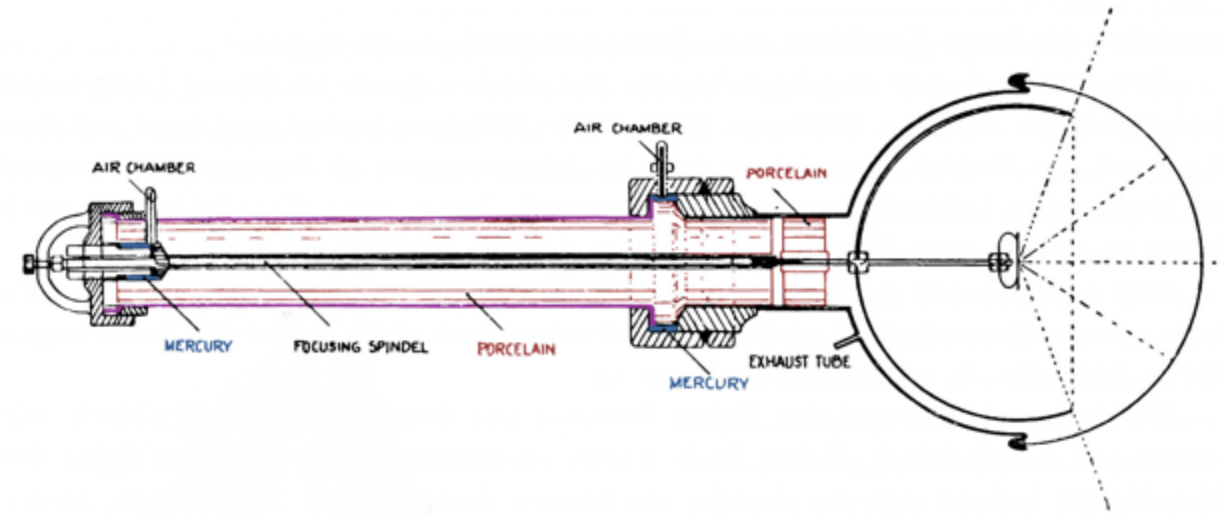
Fig. 1b. Cross-sectional drawing of the bipolar Metalix D (1926) according to Bouwers



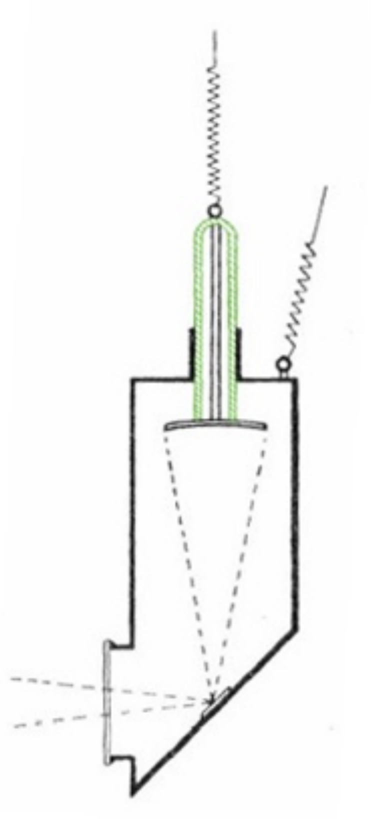
2. The metal ion tube designed by E.A. Woodward.[7] C = cathode, X = aluminum tube exterior which acts as anode at the same time, F = thick glass (green) base plate for electric isolation of the cathode, P = electric connection of the cathode, H = wooden disc to prevent implosion due to the vacuum, E = brass ring connecting the aluminum cone with the glass base plate, D = connection on the aluminum cone for the tube to the vacuum pump, B = tube to the vacuum pump.



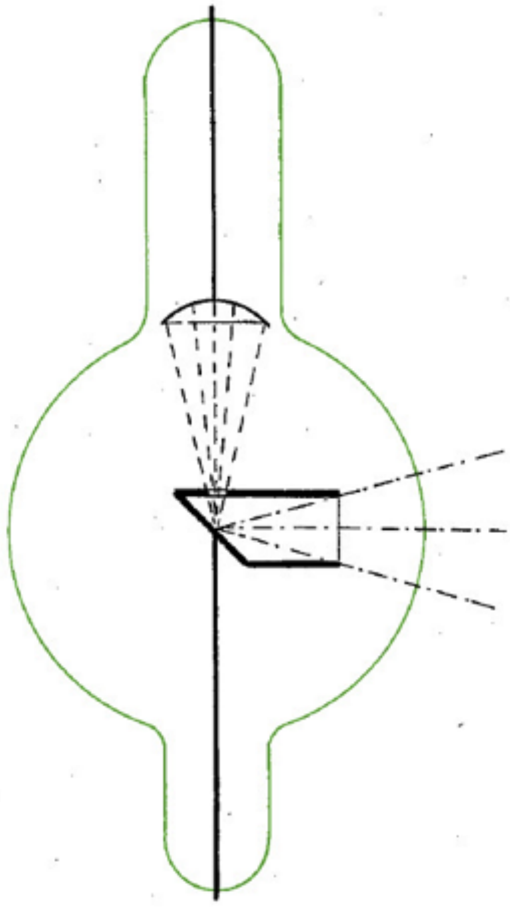
3. The metal ion tube designed by B. Davies.[8] The right half of the sphere is the cathode. Inside the left half of the sphere is a hollow metal shield. This is the anode. In the center of the sphere is the anticathode which emits the X-rays that subsequently penetrate the cathode. The high tension isolation is made of porcelain (red-brown) and use is made of mercury vacuum seals (blue). The electric isolation on the outside is made of ebonite (purple).



4. The metal ion tube designed by F.A. Lindemann. [9] This is a tube with an anode under 45 degrees and a window for the exit of the X-rays. The high tension isolation is made of glass (green).

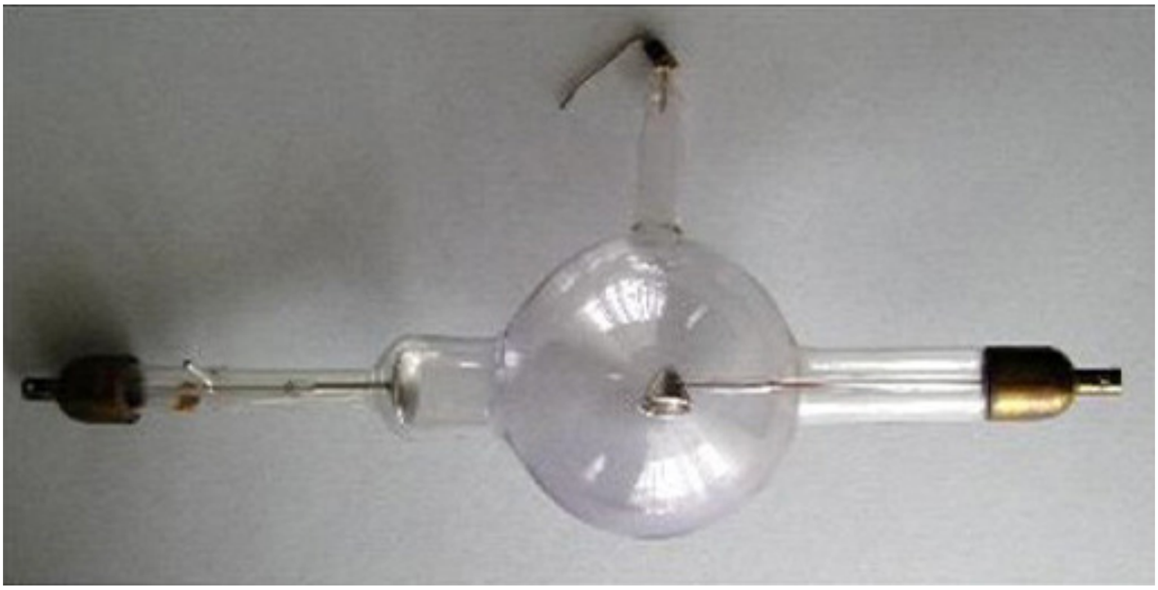


5. Internal radiation shielding around the anode as designed by M. Levy inside of an ion X-ray tube. The purpose was to limit the X-ray beam in order to reduce the amount of scattered radiation from the patient. The glass is shown in green.



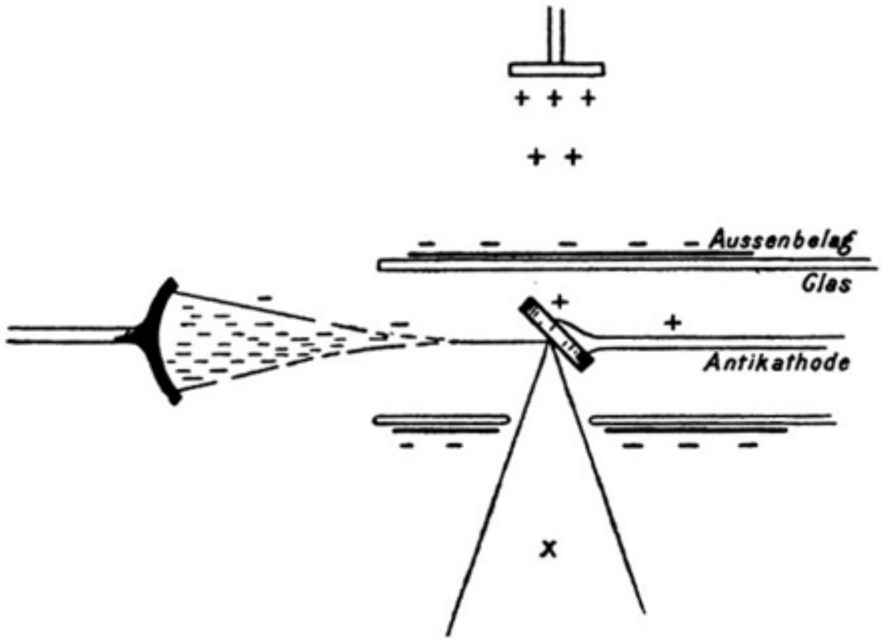
6. The platinum anode radiation shielding designed by P. Villard in the tube of V. Chabaud.[17] Fig. 6a. The ion tube. Fig. 6b. The shielded anode.

6a

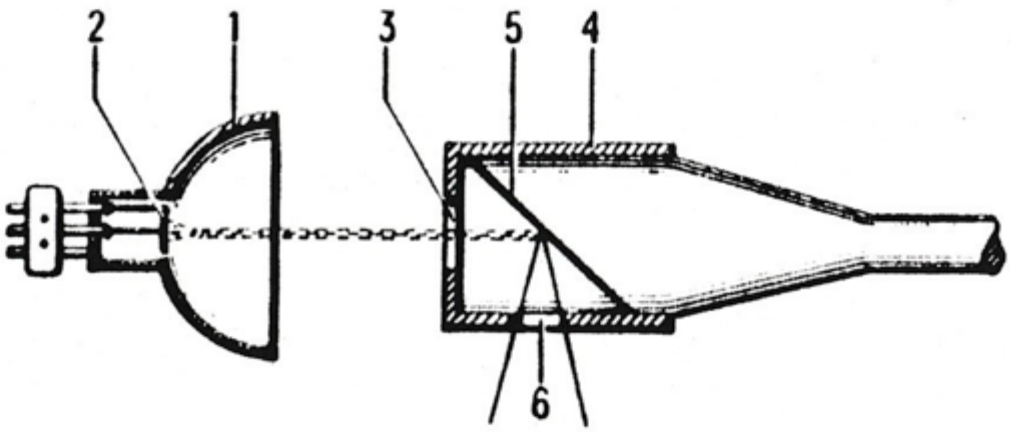


6b

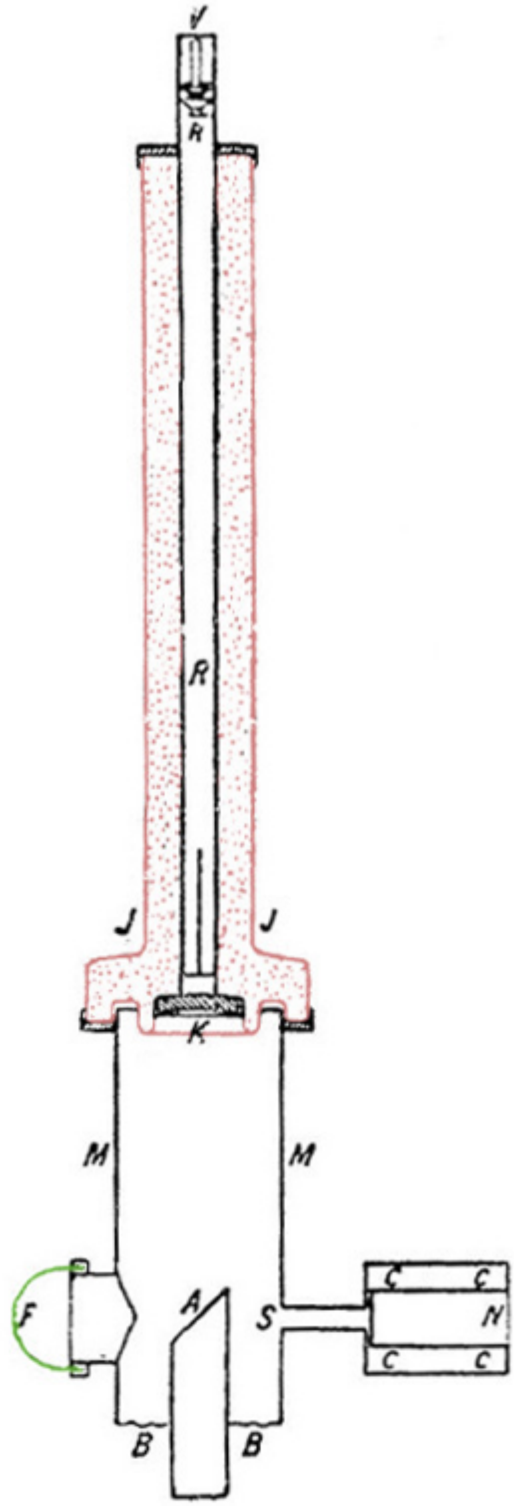
7. The special ion X-ray tube, named Ideal-Röhre, that F. Dessauer developed together with the Gundelach Company in order to be able to regulate the hardness of the tube and also to reduce the focal spot. The secondary effect of this design was that the tube was shielded internally.



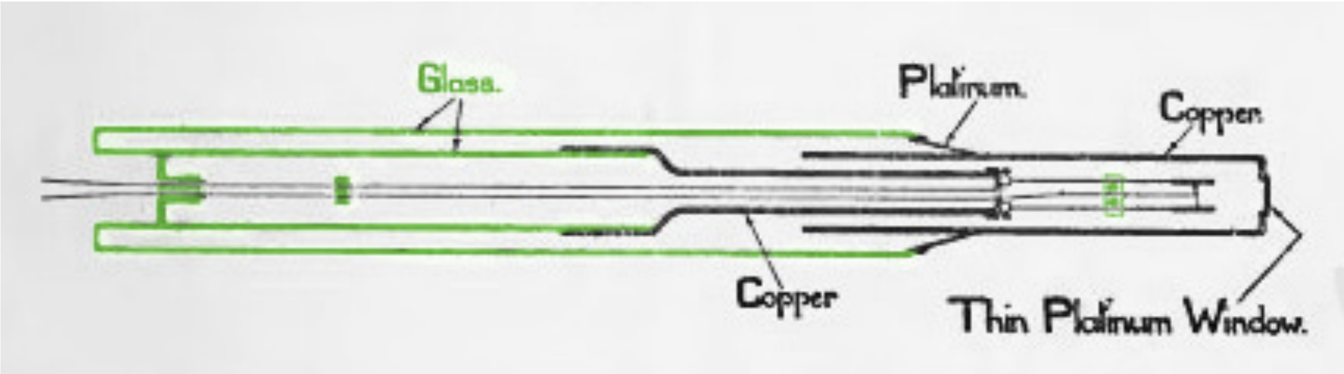
8. Modification of the Coolidge tube from 1913 with a cap on the anode for radiation shielding. The cap has two holes. 1 = cathode, 2 = incandescent cathode heating wire, 3 = hole that gives access to the electron beam, 4 = cap made of molybdenum, 5 = anode, 6 = hole for exit of the X-ray beam.



9. Cross-sectional drawing of the metal ion tube designed by L. Zehnder.[22] A = anode connected to zero potential, K = cathode, F X-ray exit window made of glass (green), J isolator made of porcelain (red-brown), M = metal exterior of the tube, V = valve, N = regenerator using C = charcoal, S = siff that prevents the charcoal to enter the tube, B = bottom with a screw thread to change the distance between anode and cathode, R = metal tube that connects the cathode with the negative high tension.



10. Metal hot-cathode tube designed by W.D. Coolidge.[23] a = copper tube exterior, b = thin cone made of platinum; soldered to a by means of silver, c = glass tube (green) for high tension isolation, d = glass inner tube (green), e = copper inner tube, f = hot cathode, g = window made of thin platinum acting as transparent anode, h cathode heating wire connected to e



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Henry Snowden Ward (1865-1911), photographer & author of the first X-ray textbook: *Practical Radiography* (May 1896)

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Abstract
This article is a biography of H. Snowden Ward, who was a professional photographer, Editor of "The Photogram" magazine, itinerant lecturer in England in 1896 on X-rays, and the author of the world's first textbook on X-rays "Practical Radiography" which was published in May 1896 and went into three editions with the later editions, 1898 and 1901, expanded and co-authored with Adolph Isenthal, a manufacturer in London of electrical apparatus and X-ray apparatus. Ward was a Fellow of the Royal Photographic Society and a founding member of the Röntgen Society. The descriptions and press opinions of his lecture on the "New Light & New Photography" are perhaps unique, but they are valuable in that they transport us back in time to the very early days of X-rays before medical men took over responsibility for X-ray applications, and the field was organised by photographers and some physicists and electrical engineers. The article concludes with a selected bibliography of Snowden Ward's books. These include publications about Charles Dickens, Geoffrey Chaucer's Canterbury Tales and William Shakespeare.

Key words: photography, X-rays, radiography, Henry Snowden Ward, Adolph Isenthal, Alfred Porter, William Morton, *The Photogram*, *Windsor Magazine*, *Strand Magazine,* Röntgen Society, Charles Dickens, William Shakespeare, Geoffrey Chaucer

Introduction

One of the earliest groups of *experts* on X-ray skiagraphy was not surprisingly photographers: both professional and amateur. {Snowden Ward & Adolph Isenthal were Fellows of the Royal Photographic Society (FRPS)} Another group were physicists/electrical engineers who had already available the necessary apparatus required for X-ray imaging in their laboratories as many had been studying electric discharge phenomena immediately before Röntgen's discovery of X-rays at the end of 1895. Of the photographers, none were more important in those early days than Henry Snowden Ward, Editor of *The Photogram* magazine which was published by the company Dawbarn & Ward of Farringdon Avenue, London. He was to publish the world's first textbook on X-rays, *Practical Radiography* in May 1896, which ran into three editions [1-4] with the second & third editions co-authored with Adolph Isenthal, a manufacturer of electrical and X-ray apparatus.

The 1st edition [1] preceded the earliest American X-ray textbook written by a physician, William James Morton (1845-1920), by only some four months [4]. It is noticeable that both Ward & Morton required assistance in writing their texts from electrical engineers: EA Robins & AE Livermore by Ward and EW Hammer (1867-1951) by Morton.

Only a single photograph showing Snowden Ward has been found (**Figure 1**). This is in the frontispiece of the 2nd edition of Ward's book [2] which has the authors Isenthal & Ward. The photograph has the phrase "The Authors as Operator & Subject" and it is thought that Ward is sitting at the left having his hand radiographed.

Snowden Ward was a founder member of the Röntgen Society, London, and served on its Council and as an editorial adviser on the *Archives of Skiagraphy*, the world's first X-ray journal: as well as on the *Journal of the Röntgen Society* which issued its first number in 1904. He also travelled around the United Kingdom lecturing on the topic of X-rays and providing demonstrations for members of the audience [5].

Prior to publication of *Practical Radiography* in May 1896, he was instrumental in publishing a Special Issue of *The Photogram* in February 1896 which was entitled *The New Light and the New Photography* [6] and in April 1896 he also wrote for the *Windsor Magazine* on *The Marvels of the New Light. Notes on the Röntgen Rays* [7]. The very popular *Strand Magazine* {which serialised Conan Doyle's Sherlock Holmes stories} of July-December 1896 published *The New Photography* by Alfred William Porter (1865-1939) an assistant Professor of Physics at University College, London [8]: but this had no input from Ward.

Once physicians & surgeons (several of whom were amateur photographers) took up the study of the X-rays, the role of photographers such as Snowden Ward became obsolete both for publishing and for travelling lectures & demonstrations and they disappear from the X-ray literature. A few items of information concerning Ward (about his books [1-3] and his membership of the Röntgen Society) have been published by Burrows in his *Pioneers & Early Years. A History of British Radiology* [9] and a brief obituary of Ward appeared in the *Journal of the Röntgen Society* in 1912 [10]. He died suddenly in New York on 6 December 1911 where he was conducting a series of lectures on Charles Dickens.

New light & new photography: *The Photogram* 1896

This 15-page February 1896 Special Issue of *The Photogram* [6] predates Snowden Ward's textbook *Practical Radiography* [1] of May 1896 and contains three papers. {**i**}

Notes on *Early Work on Invisible Rays* by E.J. Wall FRPS. {**ii**} Translation by Arthur Stanton of Röntgen's first communication [11] *On a New Kind of Rays*: reprinted from *Nature*; with a supplement giving a condensed report of Mr. A.A.C Swinton's experiments which had been published in *Nature*. Two illustrations of "Shadowgraphs" by Mr. Swinton were "Metal objects in wooden box. Exposure 4 minutes" & "Razor closed and in a cardboard case. Exposure 4 minutes". Two illustrations of "Shadowgraphs" by Mr. J.W. Gifford FRPS were "Metal discs through two sheets of cardboard & a sheet of aluminium. Aluminium between discs & plate. Exposure 10 minutes" & "Shadowgram without Crookes' tube. Metal discs through cardboard box. Exposure 10 minutes". {**iii**} *A Comparison of Cathodic and X-Rays* by E.J. Wall. {**iv**} *The Work of Mr. J.W. Gifford* by H.S. Ward.

In this same issue, *The Photogram* advertised "Lantern slides of the work of Mr. Campbell Swinton, supplied by Newton & Co., of Fleet Street, London, price two shillings & six pence each". Mr. Gifford's shadowgraphs were advertised at price one shilling and sixpence each.

Note

Two shillings & sixpence {i.e., one-quarter of 1 GB pound} would have been enormously expensive in 1896 when many wages were no more than one shilling per week. William Morton [4] advertised copies of life-sized radiographs from US$ 2.00 for a nine-week old infant down to 50 US cents for human teeth, a trout showing bones and a foreign body in the scrotum.}

Marvels of the new light: *Windsor Magazine* 1896

The *Windsor Magazine* for the April 1896 issue containing the Snowden Ward article {which was dated at the end as 12 February 1896} [7], commissioned a drawing of "Professor Röntgen at Work" (**Figure 2**) and also three photographs (**Figures 3-5**) of Mr. Gifford experimenting in his laboratory; Mr. Campbell Swinton and his apparatus used for lecturing [12]; and making Crookes' tubes in Mr. Cossor's workshop. The term *electrography* was used and not radiography, and the X-ray images were called *electrographs*. In the Introduction to his May 1896 book [1] Ward refers to terminology in the following manner. "Shadowgraphy, the hybrid but popular title which was introduced to the public in "The new light", has been dropped in favour of Radiography, a name suggested by Dr Hill Norris, and commendable for its euphony, correctness, and non-committal to any theory. Radioscopy I suggest in these pages as the only possible name for the work with fluorescents screens." He does not mention skiagraphy, skiagraphs and skiagrams which were also widely used terms in 1896, .e.g., *Archives of Skiagraphy*.

The so-called electrographs shown in the *Windsor Magazine* included typical examples early subjects used to demonstrate the photographs obtained with the X-rays. {**1**} Hand with ring. It was noted that the thumb was indistinct because it was not laid flat on the plate. {**2**} Fish. These were good test objects for showing bony detail. A plaice and a sole were shown. {**3**} Foreign object in a limb: in this case a shot embedded in a boy's arm. {**4**} Bony deformities of a foot.

New photography: *Strand Magazine* 1896

The article by Alfred Porter in the *Strand Magazine* [8] shows radiographs of hands and of small animals, as do the earlier Snowden Ward articles [6, 7] but in addition also illustrates "Radiograph of the contents of an explosive book" (**Figure 6**) as well as a photograph of the book propped open. "It is constructed on the "bon-bon" principle. One end of the cracker is attached to the cover, the other end to a box placed in a hollow inside the glued-up leaves. When the book is opened the cracker goes off and ignites the contents of the iron vessel. If this is filled with fulminate of mercury and scraps of iron, the result can be better imagined than described. What the contents are can be in part discovered by the new photographic method".

Practical Radiography 1st edition 1896

Chapter titles
The contents of the 1st edition [1] consisted of eight chapters with the following titles: of which the final chapter is historically the most interesting. {**1**} A brief history. {**2**} How to make an accumulator. {**3**} How to make an induction coil. {**4**} Apparatus for radiography. {**5**} Practical radiography: electrical. {**6**} Practical radiography: photographic. {**7**} Practical radioscopy. {**8**} Applications & probable advances.

Surgical applications
In Chapter {**8**} Snowden Ward refers to surgical applications and lists the studies he demonstrated whilst lecturing in towns in England. "In *Southport* {see later} there was a hand with a supernumerary thumb: the radiogram enabled the surgeons to decide whether amputation was advisable. In *Sunderland* there was a needle lost in a child's foot which was then successfully extracted: though previously the surgeon had probed without finding it. In *Dewsbury* there was a young woman who claimed she had lost a piece of a needle in her wrist and could still feel it. There was no trace of the needle in hand and wrist, or from wrist to elbow. The foreign substance had travelled painlessly, as needles in the muscles often will, some distance from the point of entry, but the nerve, slightly injured at the entry spot, still felt pain as if the needle were there".

Medicinal value: TB & cancer cure
"Medicinal value is claimed by Dr T.S. Middleton of New York, who does not believe in the germicidal properties, but thinks that the rays consist of streams of material particles, and can be used to convey medicinal matter and deposit it at the actual seat of the disease, thus enabling consumption and cancer to be cured".

Contents of packets
These have already been referred to in **Figure 6**, [8]. Snowden Wards comments were as follows. "The Post Office and Customs Offices have found radioscopy very valuable in detecting coins concealed in letter packets, watches and other contraband articles in books, etc. The detective force, too, both in Paris and London, have found the method useful for revealing the contents of certain suspected packets, which have proved to be infernal machines. It has been stated that letters can be read by means of the *x* Rays – and so they can when specially prepared for the purpose; but a letter written on four sides and then folded into two or three is quite safe from *x*-ray prying. And besides, the

opening and re-sealing of a letter is so simple that if anyone wished to pry they would be quite unlikely to trouble with the *x* Rays".

Flaws in metals

"Flaws in metals and bad alloying may be detected by radiography, but hardly to any useful extent at present, because the metals we most wish to test are impervious to the rays if in any useful thickness. Still there seems no real reason why radiography should not be so far improved as to enable boiler-plates and even thicker iron sheets that these to be tested by *x* Rays. It is a most important field of research, and one in which, so far as I am aware, no one is working".

False gems

"False gems may, in many cases, be detected by their *x*-ray transparency or opacity. Thus – diamonds are much more transparent than "paste", and when placed side by side, the "paste" will throw a distinct shadow. Imitation pearls and many other gems may be similarly detected".

Cattle food

"The value of cattle food for bone-forming purposes is being studied with the help of radiography. Sets of animals, carefully fed on different foods, are radiographed at various periods of their growth, and the radiograms or their skeletons compared".

Radiographing the skull

"Radiographing the skull is not difficult, though radiography of the brain will probably long be impossible. When one side of the skull is laid on the dry-plate, very beautiful detail of its structure can be obtained by long exposure, for the side near the tube is so far from the plate that it casts no distinct shadow. Tesla says that when the rays are thus passing through the brain there is a sense of sleepiness; while another worker has reported that the use of the vacuum tube close to the head causes the hair to fall out".

Lecture-demonstrations on radiography 1896

Synopsis & press opinions

Advertisements were included in all the three editions of Practical Radiography, but in the 1st edition only [1] there was an advert for "*Lecture Demonstrations on Radiography*" given by Snowden Ward. The synopsis was as follows. "A popular lecture with full demonstration, prepared in the Spring of 1896, and delivered with great success before large audiences in London and many provincial towns. The Lecture is extremely interesting, though accurate and up-to-date. The demonstration includes the work of Crookes and others that led to radiography; with the examples of results obtained by Thermography, Electrography, etc., which have been erroneously attributed to the X rays. The exhaustion of various vacuum tubes, the use of fluorescent and phosphorescent screens, and the radiographing of various objects is shown and explained. About 50 lantern slides of the results of the foremost workers are included, and the work is on a scale that can be well shown in a hall containing 1,500 people."

This synopsis in the advertisement was followed by "*Press Opinions*". "An interesting lecture" – The *Daily Chronicle*. "In London, the other evening, a remarkable lecture was delivered by Mr. H. Snowden Ward" – *The Irish Times*. "Mr. Ward is an extremely pleasant speaker, and of his enterprise there can be no doubt" – *Photography*. "The lecture was intensely attractive, and was devoid of much of the technicality which naturally was to be anticipated" – *Sunderland Daily Echo*. "The experiments were very interesting, and the lecture itself was very clear, the audience testifying by frequent applause their appreciation" – *Huddersfield Examiner*. "This, and the preceding demonstration of the "new photography" by Mr. H. Snowden Ward, have been the success of the season; the interest excited was keen and sustained, the audiences crowding the room to its fullest capacity" – *British Journal of Photography*.

Southport, Lancashire March 1896
In the 1970s, by chance in the library of my hometown, Southport, I found in the local paper, the *Southport Visitor*, an advertisement for a Snowden Ward evening lecture entitled "*The New light and the New Photography*" organised by the Southport Social Photographic Club and held in the Temperance Institute [13, 14]. The newspaper report was as follows. "The audience was composed largely of medical gentlemen, professional and amateur photographers, scientific students and hospital nurses. One of the most successful radiograms of a surgical case had been made that afternoon. The patient was a little boy with a double thumb and the exposure was less than one minute. The hand was moved after 15 seconds and from that fact the image was slightly blurred". Ward conjectured that the vacuum tube was operating for only one-quarter to one-third the exposure time. During the evening he tried to take another radiogram of the boy's hand, but the experiment failed.

***Journal of the Röntgen Society* 1905-1907**

Double thumb radiogram: Snowden Ward
A decade later Snowden Ward described in the *Journal of the Röntgen Society* the events that had occurred during the Southport lecture/demonstration in March 1896 [15] and published the radiogram of the boy's hand with a double thumb (**Figure 7**). "The accompanying print is of no great importance, save for the fact that it was one of the first radiograms upon which a successful surgical operation was based. It was made at Southport, in connection with one of my early lecture-demonstrations on X-rays; the subject the hand of a little boy, and the exposure was cut short because the child moved his thumb long before the intended exposure had been given. (It will be seen that two of the fingers had moved previously).

This cutting short of the exposure led to an interesting technical discovery, for a second plate, exposed for the full 5 minutes, which was supposed to be about the proper time for such a subject with our then available apparatus, developed nothing but a fog. Even then it was some time before my assistant and I could reconcile ourselves to cutting down the exposure to $1/10^{th}$, or less, of what we knew we had been giving, although we knew of the classic case of the Campbell-Swinton foot". [15]

Earliest radiograms in England: Campbell-Swinton
Snowden Ward's report in this July 1905 issue of the *Journal of the Röntgen Society* was directly followed by a report by A.A.Campbell-Swinton, an electrical engineer, of his own early radiograms, taken with his assistant J.C.M. Stanton [16]. He illustrated four examples. Campbell-Swinton had taken his first radiograph on 7 January 1896 and this was repeated on 8 January showing "shadows of coins, pieces of wood, ebonite & fibre and other objects through the side of a camera double-back made of mahogany". He also published "what is believed to be the first radiogram of a human hand taken in this country". This was taken on 13 January and exhibited on 16 January at the Camera Club in London, and a few days later at the Royal Institution. The hand was taken through a sheet of aluminium 0.0075 inch thick with an exposure of 20 minutes. He

obtained a much better radiogram of a hand on 18 January with an exposure of 4 minutes through a sheet of black vulcanised fibre 0.0212 inch thick.

Campbell-Swinton noted that "All these early radiograms were taken with a Crookes' tube containing some lumps of fluorescent material, and the fact that the shadows are fairly sharp is no doubt due to a portion of this fluorescent material having acted as an anti-cathode. However, at the timer we were quite unaware as to the point of origin of the rays in the tube".

Stereoscope: Snowden Ward

Snowden Ward seldom published in the Journal of the Röntgen Society but he was reported as attending the Society meeting in February 1906 when he described a new form of stereoscope then not obtainable in the country, but patented by Professor Pigeon of Dijon [17]. This followed a discussion on the paper by George Batten [18]. Then at a meeting of the Society in April 1907 Snowden Ward demonstrated this stereoscope [19].

Lists of members of the Society

In the List of Members of the Röntgen Society for 1st July 1906 his address was given as Golden Green, Tonbridge, Kent; but his name was absent in the next published List: for 1st July 1911 [20] but it is not known if he had resigned from the Society in the intervening period.

Obituaries

Introduction

Obituaries have always been a useful source for biographers and whereas that in the Journal of the Röntgen Society was limited, as would be expected, to Snowden Ward's work with the Society and with X-rays: the other obituaries located have contained a wealth of previously unknown {to this author} information, dating back to his childhood and early employment, and most surprisingly, to his giving up of his editorial work for *The Photogram* and concentrating on travelling, often in the USA. They also provide information on his wife Catherine Weed Ward, who was a well-known American photographer, and who in an **1894** issue of *The Photogram* is named in an advertisement for *The American Amateur Photographer* as the Associate Editor. When searching the Internet for obituaries of Snowden Ward the earliest reference found to an article written by him was in **1890** when he was described as "Editor of *The Practical Photographer*", [21].

The Röntgen Society

The *Journal of the Röntgen Society* published the following obituary of Snowden Ward in January 1912 [10]. "We regret to record the death of Mr. H. Snowden Ward, which took place very suddenly in New York, on 6th December **1911**, where he was conducting a series of lectures on Dickens. Mr. Ward was one of the original members of the Society and a very energetic member of Council. In the early days of Prof. Röntgen's discovery he took great interest in the "new photography" and in collaboration with Mr. A.W. Isenthal, produced "Practical Radiography" of which a 3rd edition was published. Of late years his many other duties have prevented him from continuing his work in the Society, although he took a keen interest in its proceedings, and was always ready to give advice when appealed to in connection with literary matters. The series of photogravure portraits of past Presidents which the Society publishes was originated largely by his advice and arrangement."

The British Journal of Photography

Snowden Ward's obituary was published in the *BJP* Annual Almanac for 1913 [22]. "The death of Mr. Snowden Ward took place suddenly in New York on **7 December 1911**. Mr. Ward had left England at the end of October to fulfil a series of lecturing engagements which, in the ordinary course, would have been completed within 5 months. In addition to appearing in his private capacity, he represented the **Dickens Fellowship** as a Commissioner, and was to have taken part in a number of functions arranged by members of this body in the United States. He was found unconscious in bed at the National Arts Club, New York, (his headquarters in America) on 5 December, and after an unsuccessful operation succumbed 2 days afterwards. He was interred at Albany on Saturday **9 December 1911**.

During the year or two previous to his death Henry Snowden Ward had largely withdrawn himself from the photographic journalistic world, in which for many years he had been a leading personality. His interests and inclinations had gradually led him into literary fields and he had found the Lecture Platform a welcome change from the Editorial Chair. Yet it is not too much to say that the news of his sudden death aroused a more widespread sorrow and sense of personal loss than would that of any contemporary of his in photographic circles. Few men in any walk of life had his natural quality of charming all classes of people. ...."

"He was **born** at Great Horton, near Bradford, in **1865**, and thus was only 46 at the time of his death. His father's business of stuff manufacturing did not attract the literary bent of the boy. At 18 he edited and published a magazine *The Practical Naturalist* and in **1884** became connected with the firm of Percy Lund & Co., at that time publishers and stationers catering especially for photographers. For them, Mr. Ward founded and edited *The Practical Photographer* and by his active conduct of it did much from **1889-1893** in the interests (technical, commercial & social) of professional photographers. In **1893** he married Miss Catherine Weed Barns, daughter of Mr. William Barnes of New York, and herself a most enthusiastic amateur photographer in the days when amateur photography was a more serious pursuit than it is now".

"Mr. Ward severed his connection with the Bradford firm, and with his wife founded the monthly magazine *The Photogram*, Their direction, which was one of great energy and originality, speedily caused the publication to take a leading place in photographic journalism, though its success, as a commercial property is open to doubt. The sister magazine, *The Process Photogram*, now *The Photo-Engraver's Monthly*, was founded in **1894**, and the pictorial annual *Photograms of The Year*, in the same year. ...."

"Though these publications made great demands upon his personal attention, yet he took a most active interest in photographic institutions, among them the **Royal Photographic Society**, the Photographic Convention, of which for many years he was a member of Council and President at the Canterbury meeting in **1909**, the Photographer's Benevolent Fund, and many photographic societies at whose exhibitions he was in great request as a judge. Nevertheless, he early embraced every fresh opportunity of the technical journalist. For example, on the discovery of X-rays, he was one of the first experimenters in England, wrote the first handbook on the subject, and was one of the founders of the **Röntgen Society**. He threw himself into the propagandist work of photographic records and with Sir Benjamin Stone, was one of the first to draw attention to the use of photographs in **Press Illustration**, and was ahead of his time in establishing a Bureau for the supply of photographs to the Press".

"For some year past Mr. Ward with his wife, had taken a keen interest in the application of photography to **Literary Topography**. The first outcome of their work in this field was the book on Stratford-on-Avon, dealing with the life of **Shakespeare**, and illustrated by the photographs of Mrs. Ward. This was followed by a volume dealing with the wider subject of the life of *Dickens* and the scenes of his novels, by the *Canterbury Pilgrimages*, and by a photographically illustrated edition of **Lorna Doone**. A natural step from the preparation of these books was lecturing on the subjects. For several years past Mr. Ward had visited the United States on a lecture tour round the chief cities – a strenuous life, which, it will be remembered, led to the collapse of Dickens".

Encyclopedia of 19th century photography

This Encyclopedia carries a short entry for Catherine Weed Barnes Ward (1851-1913) which gives publication dates for the topographical volumes, but not the full titles [23]. "Born in Albany, New York, 10 January **1851**, Catherine Barnes travelled with her parents to Russia in **1872**. Introduced to photography in 1886, she built her own studio in the attic of her home. She was appointed Associate Editor of *American Amateur Photographer*, wrote and lectured extensively on photography, and became known as an advocate for women in photography with her talk *Photography from a Woman's Standpoint* (**1890**). Her appointment as Editor was followed by a visit to England, where she was enrolled into the Photographic Society of Great Britain, and married the photographic journalist Henry Snowden Ward (1865-1911)".

"Together with her husband, Ward edited *The Photogram* (1894-1905), continued as *The Photographic Monthly*, and *The Process Photogram* (1895-1905), continued as *The Process Engraver's Monthly*. They collaborated on a series of topographical volumes, with photographs taken by Mrs. Ward, including Shakespeare (1896, 1897), Dickens (1903), Chaucer (1904), and Lorne Doone (1908). Snowden Ward died suddenly in New York in 1911, while on a lecture tour to promote the Dickens Centenary. Catherine returned to England, but her health deteriorated, and she died in Hadlow, Kent, 31 July 1913".

New York Times

The obituary in the *New York Times* {printed with four headlines} gave a detailed description of Snowden Ward's final illness [24]. "Henry Snowden Ward of Hadley, Kent, England, Fellow of the Royal photographic Society and husband of the former Miss Catherine Weed Barnes, the sister of William Barnes Jr., of Albany, died under unusual circumstances early yesterday morning in Miss Alston's private hospital at 26 West 61st Street, where had had been taken from the National Arts Club in Grammercy Park on Tuesday night".

"Mr. Ward had lectured on Shakespeare, Thackeray, and Dickens both in this country and Europe. He came from England 6 weeks ago to lecture in connection with the Dickens Fellowship, to the Secretaryship of which he was appointed some months ago in England. He was accompanied by his wife. Mrs. Ward went to visit her brother and sister-in-law in Albany, while Mr. Ward went on a tour of the cities lecturing on literary subjects. He had made several lecture tours in this country before".

"Mr. Ward lectured in Buffalo about a week ago, and caught a slight cold there, but didn't think much about it. He was scheduled to lecture last Tuesday night before the American Institute in the Berkeley Lyceum. His abilities as a lecturer were well known and many members of the Institute gathered in the rooms of the organisation at 8 o'clock on Tuesday evening for his lecture on the subject of "*Dickens, Thackeray and Shakespeare*". Mr. Ward, however, did not appear.".

"The audience waited until almost 9 o'clock, and was then dismissed. Several of Mr. Ward's more intimate friends hastened down to the National Arts Club in Grammercy Park, where Mr. Ward had been staying. Failing to find him anywhere on the main floor of the Club, they went up to his bedroom on one of the upper floors. Mr. Ward was unconscious on his bed. When aroused, he seemed dazed and complained of a severe pain in the ear. Dr William Seaman Bainbridge and Dr Cleveland Cady Kimball, both of 34 Grammercy Park were summoned. Mr. Ward was able to tell them that he had caught cold in Buffalo 2 weeks ago and that he had a bad earache. Then he became unconscious. He did not at any time complain of any cough or pain in the lungs. He was removed under Dr Bainbridge's direction to Miss Alston's hospital and when Dr Duel of the Manhattan Eye & Ear Hospital was summoned, he found a slight abscess in the patient's ear.

"Symptoms arousing suspicions, the physicians made tests of his spinal fluid, and of the result Dr Bainbridge said this yesterday to a TIMES reporter: 'The main's spine was literally swarming with pneumonia germs. It seemed as though they were actually devouring him.' Seeking to drain off the germs, Drs Duel & Bainbridge then performed the mastoid operation, making an outlet on the left side of the skull from the brain. The pneumonia germs increased as fast as they were drained off, however, and Mr. Ward died shortly after 1 o'clock yesterday".

"Mr. Ward was 46 years of age. He was the Editor of *The Process Engraver's Monthly*, of *Photograms of the Year*, and of several series of technical handbooks. He was born in Great Horton, Bradford, and was the son of a manufacturer named William Ward. He married Catherine Weed Barnes in 1903, she being the daughter of William Barnes of Albany and Nantucket, and the granddaughter of Thurlow Weed".

"After being education at the Bradford Technical College, Mr. Ward edited successively *The Photographers' World, The Practical Photographer* and *The Photographic Monthly*. He was one of the founders of the Roentgen Society, was a Past-President of the Photographic Convention, and an Organizing Secretary of the Legion of Frontiersmen. He had written many works on literary and technical subjects and was a member of the Authors' and the Camera Clubs".

Bibliography of books by Snowden Ward

Introduction

Dawbarn & Ward Ltd., the publishers of *The Photogram* produced a series of books known collectively as the Band of Blue Library. *Practical Radiography* [1-3] was in this series, together with three others in which Snowden Ward was involved. These were advertised at the back of *Practical Radiography*. They were entitled *Photo-Ceramics* [25] which covered "Photography applied to the decoration of plaques, pottery and other ceramic and metallic surfaces" and there were two books on Shakespeare and Stratford-on-Avon, [26, 27]. After his marriage his books were written with his wife, Catherine Weed Ward, who was responsible for taking the various photographs of cities, views and architecture which were included. No books by Snowden Ward other than *Practical Radiography* were concerned with X-rays.

It is the policy of the British Library (BL) to collect a copy of all books published in the United Kingdom and they have online an integrated catalogue which can be searched by author. {However, after a century it cannot be guaranteed that *all* Snowden Ward's works have been identified: but using the BL and other library sources most have probably been found} Using this facility I have been able to trace Snowden Ward's books, including those which he only edited, not only those published by Dawbarn & Ward for *The Photogram*, but also earlier ones published by Percy Lund & Co., before he left the firm and founded *The Photogram*; as well as later books from other publishers. A selection is given below.

Percy Lund & Company
The earliest of Snowden Ward's books, which was more a pamphlet/booklet as it was only 14 pages, was published in **1891** on *The A B C of Theosophy* [28]. His edited **1892** book was a real surprise as it was the memoirs of the Public Executioner, James Berry [29]. It has been reprinted in **1972** with a new introduction and additional appendices by Jonathan Goodman [30]. Snowden Ward's earliest historical book dealt with *Lichfield and its Cathedral* [31] with a 2nd edition published in **1893**.

Dawbarn & Ward
The two books on Shakespeare and Stratford-on-Avon, were published by Dawbarn & Ward in **1896** and **1897** [26, 27] and that on *Photo-Ceramics* in **1895** [25] as well as the three editions (**1896**, **1898** & **1901**) of *Practical Radiography* [1-3]. In **1902** a series was started entitled *The Country House Series of Practical Handbooks* [32]. In **1903** a book on photography was published [33] as well as one entitled *Profitable Hobbies* [34]. Ward's final book to be published by Dawbarn & Ward was in **1905**, the 2nd edition of *Photography for The Press* which had "been revised and very largely re-written" [35].

Other publishers
Other publishers than Dawbarn & Ward were used for Snowden Ward's books on Charles Dickens, Geoffrey Chaucer's *Canterbury Tales* and R.D. Blackmore's *Lorna Doone*. In **1903** with his wife Catherine Ward, he had published his book on Charles Dickens (which he used in his lecture tours in the USA and Europe): *The Real Dickens Land with an Outline of Dickens' Life* [36]. *The Canterbury Pilgrimages* appeared in **1904** [37] and was reprinted in **1927**. *The Land of Lorna Doone*, which is centred on Exmoor in Devon, appeared in **1908** [38] and was reprinted in **1925**. The final publication under the name of Snowden Ward appeared three years after his death, **1914**, and formed the last part of an 8-part illustrated series called *Where to Go & What to Take*, which was published by the North East Railway Company [39]. The publication date of the first issue is not known.
In the **1920s** the guidebooks by Snowden Ward, illustrated by his wife, on the topics of Chaucer's Canterbury Tales, William Shakespeare, Charles Dickens, and Lorna Doone [26, 27, 36-38] were to become increasingly popular and were reprinted from the earlier editions of the end of the 19th century & beginning of the 20th century, more than a decade after the deaths of Snowden & Catherine Ward. **Figure 8** is an example from the 1920s of the front cover of one of these reprints.

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34. Ward HS. *Profitable Hobbies*. London: Dawbarn & Ward, 1903, pp 76.
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37. Ward HS. *The Canterbury Pilgrimages*. London: AC Black, 1904, pp 321. {Reprinted 1927}
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39. Ward HS. *Where to Go & What to Take*. 8-part series. York: North East Railway Company, 1914.

Figures

Figure 1. The frontispiece of the 2nd edition (1898) of Isenthal & Ward's *Practical Radiography* [2]. Entitled "A radiographic outfit. Arranged for a demonstration by A.W. Isenthal before the Royal Photographic Society, 22nd February 1897. The authors as operator and subject." Snowden Ward is seen having his hand radiographed.

Figure 2. Artist's drawing of Röntgen in his laboratory in Wűrzburg. This is a reasonable likeness and the Leiden cells and the induction coil are clearly seen together with the photographic plate, [7]. The only error is with the X-ray tube which was a Crookes' pear-shaped tube and not a cylindrical electrical discharge tube shown .

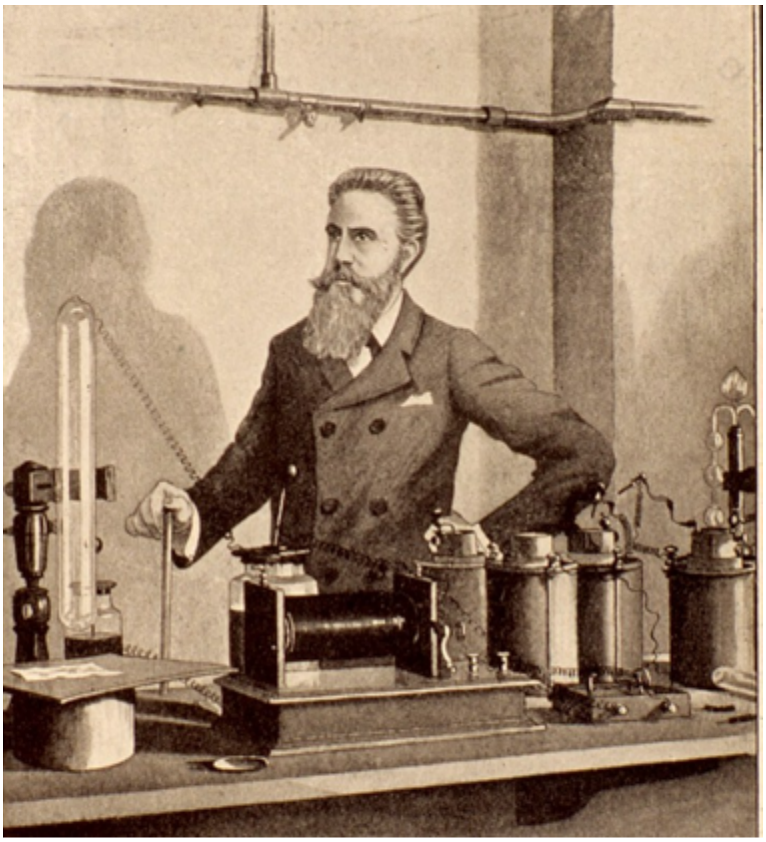


Figure 3. Entitled "Making Crookes' tubes: a corner in Mr. A.C. Cossor's workshop", [7]. A.C. Cossor was a well-known X-ray apparatus maker and advertised in the 2nd edition (1898) of Snowden Ward's book [3] as the "actual maker" of "Focus tubes with improved anode, also with movable cathode. Tubes showing different degrees of vacua. Tubes containing specimens of fluorescent and phosphorescent minerals, crystals, salts, rubies, etc. Fluorescent screens, mercury pumps, induction coils, transformers & accumulators." Their address was in Farringdon Road near to the Farringdon Avenue address of the publisher of *The Photogram*, Dawbarn & Ward.

Figure 4. Entitled "Mr. J.W. Gifford experimenting in his laboratory at Chard", [7]. This is a typically cluttered laboratory of the time. The X-ray tube being used is not the pear-shaped version, but one with a spherical bulb. There must have been ~ 100 different designs of X-ray tube by the end of 1896. Once a metal anode was introduced (rather than use the wide glass end of the pear-shaped tube as the target) and focus tubes with a curved cathode used, the pear-shaped design had become obsolete.

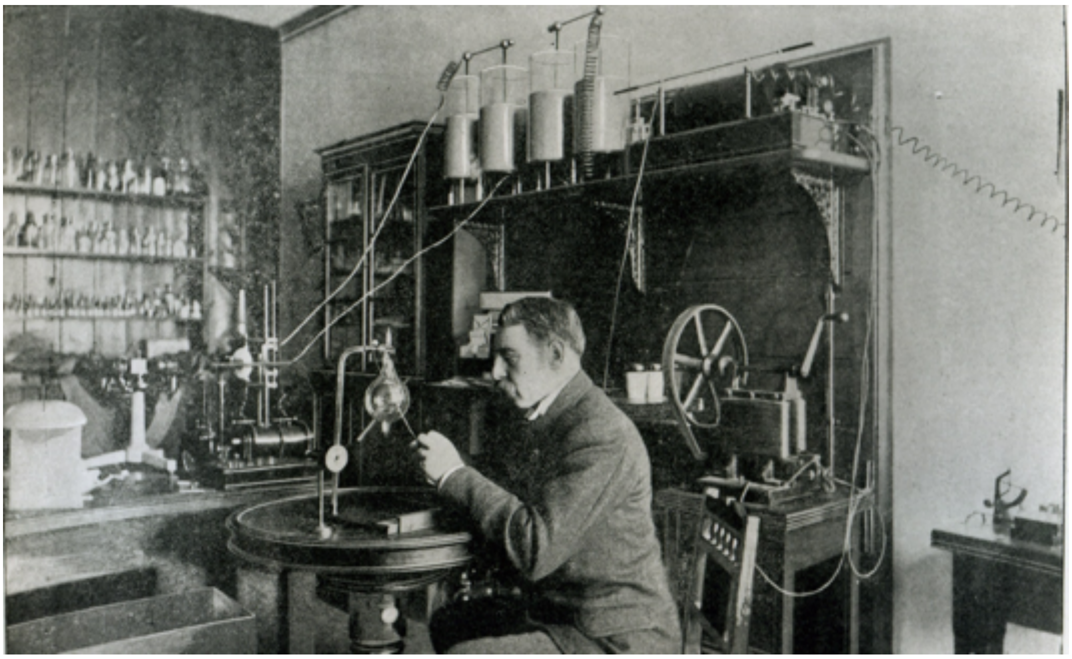


Figure 5. Entitled "Mr. A.A. Campbell-Swinton surrounded by his apparatus used in lecturing before the Royal Photographic Society", [7]. The set-up is very basic with the use of a wooden retort stand to clamp the pear-shaped Crookes' tube and a pile of books to raise it to the correct height. The lecture by Swinton was on 11th February 1896 and was the first public demonstration of the art of X-ray imaging in England [9, 12]. **Figure 1** shows a much-improved experimental arrangement one year later in 1897.

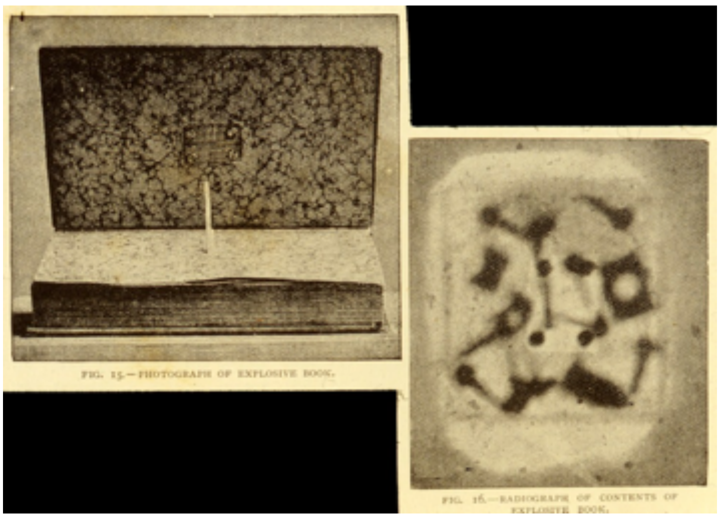
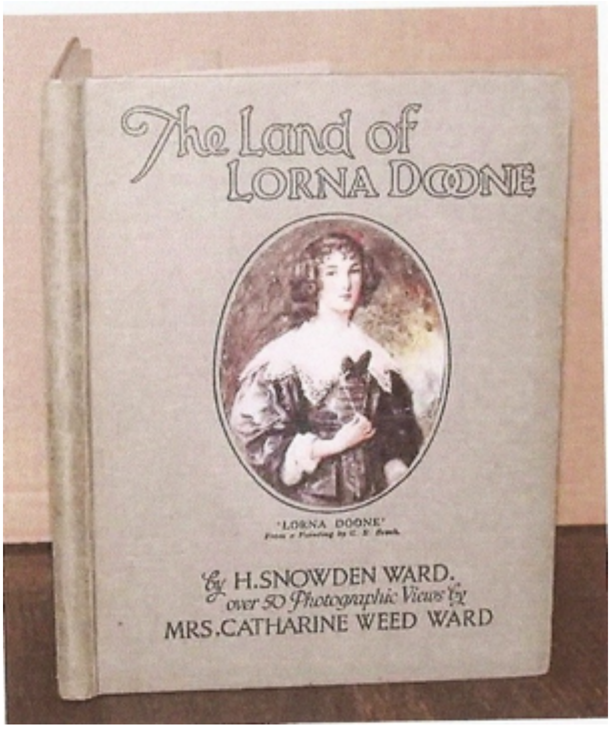


Figure 6. Ordinary photograph of the book's exterior and a radiograph of the "explosive book" [8]. This is probably the earliest X-ray mage of the contents of a terrorist device.

Figure 7. The boy's double thumb radiographed by Snowden Ward in Southport 24 March 1896 [13] and published a decade later, July 1905, in the *Journal of the Röntgen Society* [15].

Figure 8. 1920s front cover of one of Snowden Ward's guidebooks containing photographs taken by his wife [38].



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