The Invisible Light
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Contents

Editorial Notes

There has been a great deal happening since the last RHHCT Journal. Of particular interest has been events in Europe. I organized with Uwe Busch from the German Deutsches Röntgen-Museum the first ever session devoted to radiology history at ECR (European Congress of Radiology) which was held in Vienna earlier this year. This historical session was a great success and will continue as a yearly feature of ECR. As part of ECR there was an exhibition between the British institute of radiology and the Deutsches Röntgen-Museum related to the popular perception of X-rays. It was called "Lasting for a Day: ephemera in Radiology" and was based on my collection of radiological ephemera. I wish to thank Prof. Nicholas Gourtsoyiannis for his unfailing support and encouragement. We hope to have another exhibition at ECR next year.

There is an interesting collection of articles in this journal with articles on Marie Curie, Florence Stoney and X-ray Tubes.

Please send me any material of interest and in particular details of papers, books and web sites related to the history of X-rays and radioactivity.

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Officers and Committee Members of the RHHCT

The RHHCT web site

The RHHCT web site is to be found at:

www.rhhct.org.uk

I am always interested in material for the web site. Please send me material which I will consider for inclusion.

"All science is either physics or stamp collecting."

Ernest Rutherford 1871-1937

Amazing X-ray Vision!

There now is a new exhibition on popular aspects of X-rays in the display case at the British Institute of Radiology.

At the ECR in Vienna earlier this year there was a joint exhibition between the British Institute of Radiology and the Deutsches Röntgen Museum. The exhibition was on the popular aspects of the X-rays and we showed a variety of material. A series of posters of ephemera were presented and accompanying the posters there were two display cases of 3-D material. It is this 3-D material that can be seen at the case at the Institute.

The Exhibition at ECR

From the earliest days following the discovery of X-rays by Wilhelm Conrad Röntgen there has been a popular fascination with the X-rays. This "invisible light" shows many hidden things. There are things that should be revealed, such as fractures and diseases, however there is also a sense that other things revealed are best kept hidden. The X-rays can show too much. The X-ray vision sought by Dr Xavier, played by Ray Milland in the classic 1963 sci-fi film "The man with the X-ray eyes" ultimately destroyed him. He saw too much.

Much of the material in the history of radiology is transient and ephemeral. It is not usually to be found in books and libraries. The term "ephemera" covers a wide range of transient material, including tickets, labels and trade cards. The material illustrates social history, technical developments and is an evocative reminder of past times. Maurice Rickards defined ephemera as "the minor transient documents of everyday life". The study of ephemera usually involves printed items other than books. One of the first twentieth century academics to recognize the value of ephemera was John Johnson and his large collection is now in the Bodleian Library in Oxford, UK.

There is a developing academic interest in ephemera studies. A Centre for Ephemera Studies based at the University of Reading was inaugurated in 1993. As the ephemera Centre says, "over the years, there have emerged numerous collections of oddments - labels, tickets, forms, handbills, messages, stationery, advertising material - items that were intended in most cases for a brief life but which with hindsight, illuminate their time".

Display case at ECR.

Ephemera in radiology can be divided into two main types of material, the popular and the professional.

The popular material includes post cards, trade cards and cigarette cards. Many companies such as Suchards issued cards as a free promotional gift. The designs are charming and show an age now long past. More recently X-rays have been used in advertising and promotion of products as diverse as vodka and chocolate bars. In the popular imagination, Superman and his X-ray vision are as real as medical imaging. The X-rays are seen as showing reality. As it says in the introduction to a recent book of photographic portraits by Françoise Nars, "Fundamentally, there is nothing more truthful than an X-ray". There is a copy of this interesting book in the BIR library.

The professional material is the documents created by radiology departments or companies. Very little of this material has been kept in a systematic way, however where they have been preserved they illustrate how departments work and the assumptions made in clinical practice.

Congress President, Prof. Nicholas Gourtsoyiannis at the exhibition.

The exhibition at ECR looked at some of this fascinating material.

Do visit the British Institute of Radiology to see the display case. Also, consider a visit to the Deutsches Röntgen-Museum in Remscheid. The town of Remscheid-Lennep is delightful and you will be given a warm welcome.

We are always interested to see any ephemeral and popular X-ray material.

Adrian M.K. Thomas, British Institute of Radiology
http://www.bir.org.uk
Uwe Busch, Deutsches Röntgen-Museum
http://www.roentgen-museum.de

Recent historical articles:

Alexander Rzewuski (1861-1943): the forgotten pioneer of radiology.
Eur Radiol (2002) 12:2826-2827
An interesting article about the pioneer Swiss radiologist – I must admit that I knew nothing about him before reading this article. Only a few days after the announcement of the discovery of X-rays by Röntgen, Rzewuski took radiographs in Davos in Switzerland (and as it says probably in the world).

Andreas Vesalius and 500 years imaging of the brain.
HU Lemke & DEJ Linden
Health Academy 02/2002 p76-86

Vesalius and modern 3-D reconstruction of cerebral anatomy. An article by the pioneer of digital radiology.

Recent historical books:

The Head Bone's Connected to the Neck Bone: The Weird, Wacky, and Wonderful X-Ray.
Carla Killough McClafferty.
Farrar, Straus & Giroux, New York (2001) ISBN 0-374-32908-7
The author is a Radiologic Technologist (what we would call a radiographer) who lives in North Little Rock in Arkansas. The book is a popular history of early X-rays and aimed at young people. I am not sure that I quite agree with the "weird and wacky" idea – at the time what was done seemed serious and obvious and we do not know how future generations will regard our current follies that seem so serious to us. A book well worth reading.

Schools of Mines, The Beginnings of Mining and Metallurgical Education
By: Fathi Habashi http://pages.infinit.net/habashi/

The book outlines the history of these institutions, their outstanding teaching staff, and their distinguished graduates. They formed the foundation for the scientific and technical development of the mineral industry in all its sectors. More than 600 pages illustrated with 350 figures and maps of which 73 are in color, includes the history of 92 schools, over 400 biographies, over 100 selected references, and 27 pages of indexes. ISBN-2-980-3247-8-7. Published February 2003. Price Can. $ 80 + postage.

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"This isn't right, this isn't even wrong."

Attributed to the 1945 Nobel Prize Laureate in Physics, Wolfgang Pauli (1900-1958) upon reading a young physicist's paper.

Interesting web sites:

The LH Gray Memorial Trust
http://www.graylab.ac.uk/usr/lhgraytrust/home.html
http://www.graylab.ac.uk/usr/lhgraytrust/history.html
The web site celebrates the great Louis Harold Gray (1905 -1965) Gray was elected F.R.S. 1961.
The LH Gray Memorial Trust was set up in 1967 to honour the memory of Hal Gray, the distinguished British scientist who made important contributions to the application of radiation physics to biology and medicine. The LH Gray Trust was created jointly by The British Institute of Radiology, The Association for Radiation Research, and The Hospital Physicists Association.
The Gray (Gy) is the derived SI unit for absorbed dose, specific energy and kerma (kinetic energy in matter). This unit was named after Louis Harold Gray. 1 Gray is the dose of energy absorbed by a homogeneously distributed material with a mass of 1 kilogram when exposed to ionising radiation bearing 1 joule of energy. 1 Gy = 1 J/kg. The web site is quite excellent. There is reprinted a paper: "Rays instead of scalpels" from the book "My Name is Becquerel. The stories of the scientists whose names were given to the international units of measure" by Ernst Schwenk. There is a review article: "1953 and the events leading to the birth of the Gray Laboratory at Mount Vernon Hospital" by Oliver Scott. The site also contains an obituary and chronology of Hal Gray with many photographs. The L H Gray Conferences and Workshops have become established as prestigious meetings at which a high level of presentation and discussion take place and there is information about these in the site. The Secretary/Treasurer of the LH Gray Memorial trust is Dr Steven A Everett.

The Dotter Interventional Institute
http://www.ohsu.edu/dotter/
This is a very interesting web site devoted to Charles Dotter. The Dotter Interventional Institute (3181 SW Sam Jackson Park Rd. Portland, OR, 97239-3098 USA) was established in 1990. Charles T. Dotter was the father of interventional radiology and was chairman of the Department of Diagnostic Radiology at Oregon Health Sciences University from 1952 until his death in 1985. Following his early work at Cornell University, Dotter concentrated on the development of cardiovascular radiology. Intravascular balloon catheters, flow-guided catheters, safety J-tipped guide wires and the transvascular biopsy catheter were among the devices and techniques he developed in his early years. Dotter's greatest impact on radiology was the introduction of interventional radiological techniques. Dotter's introduction of transluminal angioplasty in 1964 was followed by other innovative techniques. These techniques included retrieval of intravascular foreign bodies, use of tissue adhesive for therapeutic vascular occlusion, local fibrinolysis and the use of intravascular coils, an idea that was the forerunner of expandable stents. *"The angiographic catheter can be more than a tool for passive means for diagnostic observation; used with imagination it can become an important surgical instrument."* On January 16, 1964, Charles performed the first percutaneous transluminal angioplasty of a stenotic femoral artery.

Hôpital Bretonneau.
http://www.aphp.fr/hopitaux/bretonneau.htm
An interesting site about hospitals in Paris (Hôpital Bretonneau 23, rue Joseph de Maistre, 75885 PARIS Cedex 18). The sections on local medical history on this site are excellent. Do visit this site (in French). I came across this site when researching Dr Félix Lobligeois (1874-1941) who was an important figure in early French radiology. In 1908 following a public examination various heads of X-ray departments were appointed (médecins-chefs titulaires des laboratoires d'électroradiologie) and Félix Lobligeois was appointed to Hôpital Bretonneau.

Packs and Cards
http://www.packsandcards.com
Beautiful Presentation Packs and Stamp cards from Great Britain. These attractive and collectable items are produced and published by the British Post Office. In many cases very limited numbers are produced. Smart packs containing British Post Office Stamp issues in mint condition. The stamps are featured in a colourful and informative wallet. These collectors items are far scarcer than the stamps themselves.

How Stuff Works
http://www.howstuffworks.com
HowStuffWorks is entertaining. It was originally founded as a Web site for curious people, the award-winning company now offers clear and fascinating content through various media channels to millions of readers every month. Recognized internationally as the leading provider of information on how things work, HowStuffWorks content explains the world from the inside out! There is a good section on X-rays with clear diagrams.

ECHO (Exploring and Collecting History Online (Science and Technology)
http://chnm.gmu.edu/echo/
More than ninety percent of all scientists who have ever lived are alive today. It is the goal of ECHO to record their stories and the ever-expanding, ever-accelerating history of recent science and technology using a contemporary technology well suited to such a daunting yet critical task: the Internet. It also presents a significant opportunity to enlarge the relationship between historians, their subjects (in this case scientists, doctors, engineers and others involved in their research and productions), and the broader audience for this history: students and the general public. On its most fundamental level, ECHO provides a centralized for those looking for the scattered Web sites on the history of science and technology. Its staff will annotate these sites so that it will become easier for those seeking historical materials to find exactly what they are looking for, or for the merely curious to explore topics of interest. Beyond this important service, ECHO provides tools and subsections of the site for each of its constituents. A practical guide includes information and how-to sections on Web-based oral history projects, handling on line contributions from historical participants, and the effective presentation of historical material. ECHO is funded by the Alfred P Sloan Foundation.

National Radiological Protection Board
http://www.nrpb.org/
The National Radiological Protection Board was created by the Radiological Protection Act 1970. This web site is devoted to the work of the NRPB. There are sections on understanding radiation and radiation accidents. The section on medical radiation has yet to be developed.
Issue 2 of the NRPB eBulletin is now on the NRPB website:
www.nrpb.org/publications/bulletin/no2/index.htm

The Society for Radiological Protection
http://www.srp-uk.org
The UK Associate Society affiliated to the International Radiation Protection Association. It is a major Scientific Society for all who are professionally concerned with the safety aspects of ionising and non-ionising radiation in education, central and local government, industry, medicine and research.

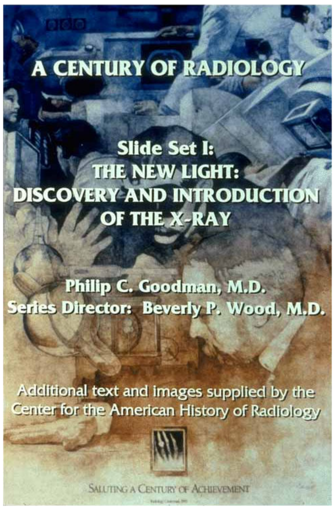
The 24-Hour Museum
http://www.24hourmuseum.org.uk/
You can visit the world's first national virtual museum, the 24 Hour Museum. The site was first launched in May 1999 under joint management from mda and Campaign for Museums. We became independent in April 2001. Based in Brighton, they are a registered charity and funded by the Department of Culture Media & Sport through Resource. The aim is to promote UK museums galleries and heritage attractions and develop new audiences. The site was launched in 1999 as a partnership project between the mda and the Campaign for Museums. The 24 Hour Museum is the UK's national virtual museum.

The growing database includes over 2,500 museums, galleries and heritage attractions. You can search our site for what's on in the UK by place, date or by any subject you choose. We feature regular news and exhibition stories on the site, along with Internet trails produced in partnership with museums and galleries. The 24 Hour Museum aims to encourage visitors out into real attractions around the country and show them exciting activities all over the UK, all year round. You can suggest an institution for the database. Contact them at info@24hourmuseum.org.uk . Priority is given to non-profit making organisations but they do occasionally include commercial institutions. They were winner of BT/New Statesman New Media Award for best education website 2001.

The editor is Jon Pratty editor@24hourmuseum.org.uk

A Philatelic History of Radiology
http://www.xray.hmc.psu.edu/rci/contents_4.html
This is a project of the USA Radiology Centennial, Inc. and is a consortium honoring a century of discovery and achievement. The material has been collected by Chuck Mitchell. The images that appear on this Pennsylvania State University web site belong in

a collection that Radiology Centennial, Inc copyrighted in 1993. These images are intended to further scientific and educational knowledge about the history of radiology.



A Century of Radiology.
http://www.xray.hmc.psu.edu/rci/centennial.html
This is a project of Radiology Centennial, Inc. and is a consortium honoring a century of discovery and achievement. The slide sets are presented on the web with the topics being:

1. The New Light: Discovery and Introduction
2. The X-Ray Enters the Hospital
3. Marketing the Miracle: Early X-Ray Advertising
4. A Philatelic History of Radiology
5. Radiation Physics (Web version forthcoming)
6. Oral and Maxillofacial Radiology
7. A History of Women in Radiology
8. Radiation and the Popular Imagination
9. Radiation Oncology
10. Radiological Technologists (slide set currently unavailable)
11. Diagnostic Ultrasound (Web version forthcoming)
12. African Americans in Radiology (Web version forthcoming)
13. Breast Imaging (Web version forthcoming)

National Radiological Protection Board (NRPB)
The March 2003 NRPB Bulletin is now published on the NRPB Web site:
http://www.nrpb.org/publications/bulletin/no3/index.htm
Contents include:-
The Health Protection Agency, NRPB changes, COMARE view on Bradwell cancer cluster claims, Nuclear powered satellite plans, European Committee on Radiation Risk & 3rd epidemiological study of participants in the UK atmospheric nuclear weapons tests.
The following is copied from the site:

A third epidemiological analysis has been carried out of participants in the UK atmospheric nuclear weapons testing programme. This covered mortality to the end of 1998 – a further eight years compared with the previous analysis. Overall mortality and incidence of cancer continued to be very similar in test veterans and in a matched control group. Reports of a recent raised risk of multiple myeloma amongst test veterans were not substantiated. However, the possibility that test participation caused a small absolute risk of leukaemia other than chronic lymphatic leukaemia cannot be ruled out.

In the 1950s and 1960s the United Kingdom conducted a series of atmospheric tests of nuclear weapons and an associated experimental programme. The experimental programme took place at Maralinga in Australia. It started in 1953 and clean-up operations continued until 1967.

Two epidemiological analyses of UK participants in the UK atmospheric nuclear weapons testing programme have already been published. Both considered all causes of mortality and incidence of cancer. The first analysis, published in 1988, covered mortality to the end of 1983. The second, published in 1993, extended this follow-up period by seven years to the end of 1990. A third epidemiological analysis, covering mortality to the end of 1998, has recently been published in the peer reviewed literature) and also as an NRPB report. The fuller papers give the definitive account.

Both the first and second published analyses suggested that test participation had no detectable effect on life expectancy or on the total risk of cancer. However, looking at individual causes, the first analysis found evidence for an increased risk of leukaemia and multiple myeloma, both for mortality and incidence, among the test participants compared to the controls . However, it was concluded in the later, second, analysis that the earlier excesses of these cancers appeared to have been chance findings, although the possibility that test participation may have caused a small risk of leukaemia in the early years after the tests could not be completely ruled out.

Overall levels of mortality and cancer incidence in UK nuclear weapons test participants have continued to be similar to those in a matched control group, and overall mortality has remained lower than expected from national rates. There was no evidence of an increased raised risk of multiple myeloma among test participants in recent years, and the suggestion in the first analysis of this cohort of a raised myeloma risk relative to controls is likely to have been a chance finding. There was some evidence of a raised risk of leukaemia other than CLL among test participants relative to controls, particularly in the early years after the tests, although a small risk may have persisted more recently. This could be a chance finding, in view of low rates among the controls and the generally small radiation doses recorded for test participants. However, the possibility that test participation caused a small absolute risk of leukaemia other than CLL cannot be ruled out.

Welcome to Kilokat's Antique Light Bulb Site...
http://www.bulbcollector.com/

"This site was first created in November of 1997 with the hope of meeting other antique light bulb and vacuum tube collectors on the Internet. Over the years I've met some interesting people through this site and have added many things to my collection and have helped other collectors add to their growing collections. This site continues on with its original purpose of sharing items from my collection through pictures. Such items include antique light bulbs, early radio tubes and box art, Geissler and Crookes discharge tubes, x-ray tubes, Aerolux figural neon glow lights, vintage Christmas lights and more. I invite visitors to browse and download old lighting catalogs, early historical books on lighting, and a vast assortment of other paper items from the paper archives made available through this site. The gallery contains over 600 pictures of items from my personal collection with full descriptions that accompany most pictures. A discussion board exists to allow collectors and historians to network with others and post classified ads. Currently the antique light bulb forum is home to over 150 members who share the same common interests. Comments and additional information about the items pictured here are always welcome as are submitted and credited articles concerning the collecting and history of antique light bulbs."

kilokat7@bulbcollector.com

"What is it that has called you suddenly out of nothingness to enjoy for a brief while a spectacle that remains quite indifferent to you?"

Edwin Schrödinger, Physicist.

39th ISHM Congress
http://39ishmcongress2004.it
The next International Congress of ISHM which will be held in the southern part of Italy - an area once called Magna Graecia -from Sunday 5 September till Friday 10 September 2004.
The 39th ISHM Congress will bring together the most distinguished scholars on history of medicine towards the Metapontum area, the land of Alcmeon and Pythagoras, from where the roots of scientific medicine spread innovative health sciences teachings.
The Congress venue will be a luxury resort village, along a sea-side area, deep in a pine wood forest, which offers the best services for conventions in a sunny and relaxing atmosphere.

TOPICS

- Medicine and Archaeology
- Medicine and Mathematics for Health Devices
- The Scientific Method in Experimental Medicine
- The Role of Placebo in Clinical Trial
- Naval and Port Medicine
- History of Medicine in Health Sciences Education
- History of Plastic and Cosmetic Surgery
- History of Sports Medicine

VARIA
POSTERS
"M.D. GRMEK" MEMORIAL COURSE ON MEDICINE AND PHILOSOPHY

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BRITISH SOCIETY FOR THE HISTORY OF MEDICINE

20TH CONGRESS, University of Reading,
4th – 7th September 2003

The University of Reading is the venue for the 20th Congress of the British Society for the History of Medicine from Thursday 4 to Sunday 7 September 2003. Together with the University, the host societies are the Reading Pathological Society, the Berkshire Medical Heritage Centre and the Healthcare History Society of Berkshire.

Reading is very accessible. It is served by the M4 motorway. It lies not far from both the M40 and the M3 for journeys north and south. There are direct rail links from all parts of the country and frequent trains on the 25 minute journey from London Paddington. There is a Railair bus from London Heathrow and a direct train service from London Gatwick airport.

Within the University, the well-known Departments of History and of Classics have particular relevance to the Congress. The University has a long tradition of teaching biosciences and agricultural subjects, and this is reflected in one session of the Congress programme. The Cole Library of Early Medicine and Anatomy can be visited and will provide the basis for one exhibition; there will be others in the Department of Typography and Graphic Communication and possibly in the Museum of English Rural Life (subject to refurbishment).

The Royal Berkshire Hospital has a long and proud history. A visit is planned to see several historic features including the premises of the Reading Pathological Society, a suite of rooms built for the Society and its Library in 1883 and still used by them. Following that visit on Friday 5 September, there will be an optional excursion to Mapledurham House, the home of the Blount family for over 500 years, located on the River Thames 4 miles upstream of Reading. A guided tour of the house will be followed by a sit-down buffet supper at the Caversham Heath Golf Club on the Mapledurham Estate. The Congress Dinner will take place at Whiteknights Hall on Saturday 6 September.

For the Congress, in order to reflect local strengths and enthusiasms as well as offering the chance to explore topics of wide interest and appeal, the following themes have been chosen:

Ancient and mediaeval medicine
Medicine in the Thames Valley
Veterinary science, agriculture and medicine
Art, architecture and the environment
'Varia' (Open session)

Registration:
Registration forms and payments should be sent to the Deputy Congress Organiser:
Jill Seegers, 13 Queens Court, Gatehampton Road, Goring-on-Thames, Reading RG8 0EW.
Her telephone number is 01491 875740 and e-mail: jill@seegers.freeserve.co.uk

Further information may be obtained from the Congress Organiser:
Mr Dermot O'Rourke, 38 Stanhope Road, Reading RG2 7HN.
E-mail: dermot@ouvip.com

Museum of Radiology, Palermo
http://www.unipa.it/~radpa/museo/museo.html

On 11th December 1995 in Palermo there was the inauguration of the Museum of Radiology, during the Celebrations of the Centennial of the discovery of X-rays by W. C. Röntgen (1885-1995). This Museum was conceived by Prof. Adelfio Elio Cardinale, Director of the Institute of Radiology "Pietro Cignolini" - University of Palermo, Italy.

The museum is directed by Prof. Marcello De Maria.

At present in the world there exist about ten Museums devoted to the history of Radiology, the most important of which in Europe is the Deutsches Röntgen Museum in Remscheid Lennep, Röntgen's birthplace.

On display in the Museum are instruments and devices of particular historical value, but also books, journals, correspondence of various kinds, widely used materials and commonly used apparatuses that bear witness to the development of our discipline.

The kind concession of material by the heirs of the pioneers of Italian Radiology and by radiologists of old schools made it possible to set up the Museum. This Museum is inside the Radiology Institute, sharing the spaces occupied by the most sophisticated and modern devices and hence establishing a continual comparison between past and present.

The Museum of Radiology came into being with the hope of creating in all radiologists an historical memory backing up their high professional skill.
Address your comment and suggestion to:

Prof. Marcello De Maria
Institute of Radiology
University of Palermo
Via del Vespro, 127
90127 - Palermo, Italy
email: museorad@unipa.it

Obituary - Patricia Morley

Pat Morley made an immense contribution to radiology especially ultrasound. Her extensive pioneering role and major commitment greatly benefited patient care, changed the practice of radiology and attracted much international acclaim. Born in Bearsden, Pat moved to Kent with her family when young. Qualifying in medicine in 1953 at Westminster Hospital, London where she gained a scholarship. She then joined the Royal Navy - among the first female doctors to be a Surgeon Lieutenant RN. There she first met Neil, a Surgeon Lieutenant RNVR, and her future husband. They later moved to Edinburgh where Pat trained as a radiologist.
In 1963 Pat moved to Glasgow and began to look for a post in radiology. At that time the late Professor Ian Donald, that brilliant pioneer in medical ultrasound, was very much in need of a young radiologist to be

fully committed to clinical ultrasound. Pat was the ideal person, she joined the Radiology Department at the Western Infirmary, Glasgow, and an outstanding partnership began. Pat quickly became immersed in medical ultrasound achieving remarkable results in this new field. To many the interpretation of these early scans required much constructive imagination and was often open to ridicule. Pat, seeing the potential of ultrasound, remained committed and single-minded, often working to the 'small hours' and overcame many difficulties. Her many publications, along with her colleague the late Dr Ellis Barnett, soon gained recognition and the sceptics were won round. Their textbook *Clinical Diagnostic Ultrasound* with subsequent editions has been the leading authority for many years. Added to this she was in much demand as a keynote speaker. Her reputation attracted many visitors from the UK and overseas to the Department and to attend training courses in Glasgow.

As a young radiologist she received the Couch award from the Royal College of Radiologists for the best paper by a junior doctor and in 1980 she was made a Fellow. From 1982 to 1984 Pat was President of the prestigious British Medical Ultrasound Society. One of her lasting influences was to initiate the establishment of the Society's Historical Collection to which, following her retirement, she donated her very large library of ultrasound books and papers. As Chairman of the Scientific Committee she contributed enormously to the highly successful 1982 meeting of the World Federation of Ultrasound in Medicine and Biology in Brighton. Pat's pioneering role and her hard work for BMUS was recognised in 1994 when she was made an Honorary Member, an honour also bestowed on her by the American Institute of Ultrasound in Medicine.

Pat Morley was an 'accomplished' lady - appearing perhaps austere and sometimes direct at first meeting - she was always determined in resolve, of independent mind and sincere in her motives but nonetheless she had a witty sense of humour and a glorious smile. In her free time Pat had varied interests including gardening, ornithology, wild flowers, flying (she once had a pilot's licence) and cooking, but was happiest in her large garden at Boquhan with Neil, their four children Carolyn, David, Alistair and Christopher and friends. Sadly Alzheimer's disease marred her last few years during which she was lovingly cared for by Neil and her family and later at Bannockburn Hospital.

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Patricia Morley MB, BS, DMRD(Edin.), FRCR, FRCP(Glas.), born Bearsden 19th July 1929, Consultant Radiologist with a major interest in Ultrasound, died Bannockburn Hospital 2nd February 2003.

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21st Century Science & Technology Magazine.

The Winter 2002-2003 issue of 21st Century Science & Technology magazine features a new study of the life and science of Marie Sklodowska Curie, including her two trips to America in the 1920s. Part of this fascinating new work is displayed on their website http://www.21stcenturysciencetech.com .

"Marie Sklodowska Curie: The Woman Who Opened the Nuclear Age"
by Denise Ham

http://www.21stcenturysciencetech.com/articles/wint02-03/MarieSklodowskaCurie.html

"Re-creating the Curie Experiment to Measure Radioactivity"

http://www.21stcenturysciencetech.com/articles/wint02-03/MarieSklodowskaCurie.html#Curie%20Experiment

Marie Sklodowska Curie:
The Woman Who Opened The Nuclear Age

by Denise Ham

A new look at a revolutionary scientist's passion for truth, and how she inspired a generation of Americans.

(Excerpted from 21st Century, Winter 2002–2003, pp. 30-68)

In my quest to examine the life of Marie Curie, I had the good fortune to rediscover her life's work, particularly her discovery of polonium and radium, and her great discovery concerning the nature of the atom. In this journey, I was happy to become intimately aware that discovery itself, is an issue of passion. It surprised me considerably that my understanding of her work grew enormously, because I simply loved trying to understand that which she discovered. Since my formal education is more than bereft, especially in science, I think that I am fortunate in being able to discover in myself that very passion for knowledge which drives the creative individual to make critical discoveries that transform the physical universe. I have many people to thank for helping me in this project, which took more than a year; foremost, I wish to thank Madame Marie Sklodowska Curie, and say that her life is an inspiration which I have loved.

Part I
A Commitment to Truth

The year 2003 is the 100th anniversary of Madame Curie's first Nobel Prize. In 1903, she, along with her husband, Pierre Curie, and the physicist Henri Becquerel, won the prestigious prize in physics for their joint work in radioactivity. It was only the third year that the prize had been given, and Marie was the first woman to receive it. Eight years later, Marie Curie received an unprecedented second Nobel Prize, this time in chemistry, for her work with radium.
The genius of Marie Curie can best be understood from the standpoint of her commitment to truth. Curie was a friend and colleague of the great Russian scientist Vladimir Vernadsky. Vernadsky spent a great deal of time working in the Paris Radium Institute, which she created in 1914, and ran until her death in 1934. Indeed, our biosphere had been transformed by the creative work of Curie, Vernadsky, Pasteur, and many others—a change imposed upon it via cognition.

Madame Curie's discovery of the radioactive substances radium and polonium, her initial hypothesis on the nature of uranium being a radioactive substance (she was the first to use the term, "radioactivity"), and her correct insight into the power of uranium (and that of all radioactive substances) as derived from the atom itself, was revolutionary. Her hypothesis of the existence of other radioactive substances, and her relentless search for those substances in mountains of discarded pitchblende (a uranium ore), under the most deplorable and hazardous conditions, is the stuff legends are made of—but it is also true.

Marie and Pierre Curie's discovery totally transformed the physical universe in which we live. Although it is true (and often repeated) that Marie and Pierre Curie's work in radioactive substances took a toll on their physical well-being, they would not want to be remembered as "victims" or "martyrs" to the nuclear age. They were deeply committed scientists, who loved truth and beauty, who made significant discoveries that alleviated human suffering, and left a legacy to mankind to be cherished forever.

Marie Sklodowska Curie was not simply a great scientist; she was a magnificent human being, and her love of science and her commitment to truth were reflected in her personal character, which was beyond reproach. To understand her commitment to scientific truth, one must understand the passion behind it. A too often misused word, passion is really the emotional guiding principle behind creative discovery. Creativity without passion, does not exist.

Marie and Pierre Curie's work in radioactivity revolutionized science in the late 19th Century. Marie Curie's hypothesis that radiation was "an atomic property" transformed forever how man would view the atom. There are some biographers who have said that this, and only this, was Marie Curie's great discovery, but that is not true. It was only the first step, which she boldly took, in her 36-year odyssey with radioactive substances. In discovering the nature of nuclear power, much of her work was intimately tied to medical research in particular the use of X-rays for diagnosis, and radioisotopes for cancer treatment. The later discoveries in fission, which would prove to be the next step in harnessing the power of the atom for energy production, were later accomplished by her admirer, another woman, Lise Meitner.

The attack against nuclear energy, and the fear of nuclear science by the population today, is an attack against all scientific progress. The irony is almost too funny: Nuclear science was created and developed by the fairer sex! The idea behind the discoveries was to better mankind, by creating new cures for disease, and producing cheap energy for the planet.

Another irony is the fact that the American population had a love affair with Marie Curie. She was invited to this country twice in the 1920s, and millions of women contributed money to buy her a supply of expensive and rare radium for her research. Radium, one of the most radioactive substances, was discovered by Marie back in 1898.

In discovering a new, renewable resource for mankind, progress could be attained. The world's population could thrive. The zero-population growth movement's ideology would be the laughingstock of future generations. The world needs this science, and it needs more scientists of the caliber of Marie Sklodowska Curie who said: "Nothing in life is to be feared—it is only to be understood."

Manya Sklodowska: The Story of Marie Curie's Youth

Manya Sklodowska was the youngest of the five children of Vladyslow Sklodowski and Bronislawa (née Boguska) Sklodowska, born November 7, 1867, in Warsaw, Poland. Since 1795, Poland had been cut up and absorbed into three countries: To the east was Russia (including Warsaw); to the south was the Austrian Empire; and to the west was Prussia. Despite the fact that Poland was not listed on any map of the time, the national identity, language, and culture of Poland never died.
In the 19th Century, there were two uprisings against the Russian masters, the second one launched five years before Manya's birth. During that revolution, thousands were killed, 10,000 Poles were sent to Siberia, and a minority grouping escaped to Paris. Both of Marie's parents had brothers who were sent to Siberia, and one uncle went into exile to France.

Manya's parents were also revolutionaries, but they believed in revolution through ideas. Members of the intelligentsia, the Sklodowskis believed that Poland could become free only through the development of the mind—science—and through much hard intellectual work. Twenty-five years before his youngest daughter's birth, Vladyslow, a teacher of physics and chemistry, wrote a poem in which he exhorts his countrymen to achieve freedom, not by picking up arms, but by achieving freedom in the search for truth:

Separated, divided, we are individual and helpless, each looking into the future with apprehension, with fear, each preoccupied with his own small worries, each pursuing a fainthearted course on a narrow road.

Our hearts and minds are busy, our souls no longer house great emotion. All we are is cold, dark, silent, barren.

But suddenly, the storm roars, the thunder cracks. The foundation of the world shakes. Satan's powers cringe, agonized, in fear. This is the end of the age of error and of treason.

Let us break this armor of ice that binds our chests Let us begin today, bring stones to build the temple of truth, the temple of freedom. Let our willpower cure our crippled souls. Let our hard work prove to the world, to God, to our country our worth. . . .

"To the future!" Let us lift our glasses, Dear Brother. Let us offer our pain and our lives to that future. Work, love, and live Brothers! [as cited in Quinn 1995]

Vladaslow recognized that an armed revolution against the much stronger Russia, would amount to defeat. Like many intellectuals in Poland, he thought that education of all Poles, armed with science and technology, must be the answer to achieving a secure nation-state. Unlike many European countries, the division of classes in Poland was not by "royal birth," but was based on the educated versus the uneducated. The Sklodowskis and their children, knew that the only route to nationhood was through the elevation of the peasantry by education.

Vladaslow Sklodowski used his children's playtime for pedagogy, educating them in science, mathematics, literature, and poetry. For example, Manya and her father exchanged letters, while she was working as a governess, in which he posed mathematical problems, and she sent her solutions in her answering letters. In nature trips to the Carpathian Mountains, Vladaslow sat with his children, and taught them the scientific phenomenon of sunsets.

More often, he would read poetry and literature to them in one of the five languages he knew, while simultaneously translating the work into Polish. In fact, for a while, Manya, the woman who would become one of the greatest scientists of the 20th Century, seriously contemplated the idea of becoming a writer, or a poet. As the youngest child, she quickly learned to read at the age of four, and entered school two years younger than her peers. She mastered Russian, which was the required tongue at school and in professional life in Warsaw.

The Russian authorities had decided to wipe out any trace of "Polish" identity, so all lessons were taught in Russian. Eve Curie describes in her biography of her mother, Madame Curie, how much the Polish children hated this system. There was a conscious conspiracy in Poland between the teachers and students. There were two sets of lessons, and two sets of books in the grammar schools. For example: A lesson in Polish history, spoken in Polish, would be given by a teacher, but if the Russian masters were to suddenly come into the school, a warning signal was communicated, and the "proper" books, would appear, and Russian would be spoken. The penalty for being caught teaching in Polish was a trip to Siberia.

At the age of 16, Manya graduated, receiving the gold medal for finishing first among girls in Warsaw. Her father decided that because of her hard school life, she needed a rest after graduation, and he sent her to the countryside to live with her cousins for a year.

Manya's older brother, Josef, had studied medicine in Warsaw, but no higher education was offered for the young women in Poland, Therefore, when her oldest sister, Bronya, decided to study medicine, her choice was to go to St. Petersburg or France, both of which entailed financial concerns for the family. Years earlier, Father Sklodowski's beliefs had enraged the Russian school bureaucrats, and he was moved from being one of Warsaw's top teachers in high school, to ever lower-paying positions. Also, Mrs. Sklodowska had succumbed to tuberculosis years earlier, so the only paycheck in the household was far from enough to send young Bronya away from Poland to study medicine.

Although Manya Sklodowska also wished to further her studies, she gladly offered to go to work to help put Bronya through school in Paris, thus demonstrating one of the hallmarks of her character, her selflessness and her love of others. Although she was only 17 years old, she decided to work as a governess in a small Polish village, hundreds of miles from Warsaw. She earned 500 rubles a month, which was a hefty sum for a young girl, and her room and board were provided for, so that the bulk of her earnings could be sent to her sister.

Bronya promised Manya that she would take care of her when her turn came to study, and that promise was kept. Throughout their lives, each sister worked tirelessly on behalf of the other. Their devotion was mutual.

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The significance of Becquerel's discovery was not immediately acclaimed by many scientists. It was thought interesting, but did not generate much enthusiasm, because it was not understood. Marie and Pierre read Becquerel's paper, and Marie decided to adopt the idea as the basis for her doctoral thesis. Meanwhile, Marie and Pierre had their first daughter, Irène, in September 1897. Irène would follow in her mother's footsteps in science, and she and her husband, Frédéric Joliot, would discover artificial radioactivity, winning the Nobel Prize in Physics in 1935.

Marie began her experiments at Pierre's teaching lab, the School of Physics and Chemistry, with the approval of the director, M. Schützenberger. Pierre had been at the school nearly 15 years, and the kindly director (who was called Papa Schutz) helped the Curies in countless ways.

Marie's plan of attack, was to see whether this property of "radiation" existed in the other known elements on the Periodic Table. Pierre helped her by giving her complete access to his quartz piezo-electrometer, to measure the electrical charge that was known to be emitted from uranium salts. Marie's experiment was to gather all the known elements she could beg from laboratories and university departments, and to put them all to the test. She would put her substance on a small metal plate, opposite another metal plate, which would operate as a condenser. She used the electrometer to see whether there was an electric current in the air between the plates.

She tested all the known elements and minerals, with complete thoroughness, over and over, and shortly found one other element, thorium, which generated electrical activity. Then, she used the electrometer to measure the intensity of the current, and using different compounds of uranium and thorium, she found that what mattered was the amount of uranium present, not whether it was wet or dry, powdered or solid. Marie wrote that radiation energy had a completely different genesis from chemical generation and must come from the atom itself. It was not the interaction of molecules, or new shapes of molecules as in a chemical reaction. In her experiments, she included two minerals, pitchblende and chalcolite, ores from which uranium is extracted.

When she measured pitchblende that was devoid of uranium, she discovered that the electrical conductivity was four times greater than that of uranium itself, and that the conductivity of chalcolite was twice as great. This was the paradox she confronted: How could this be possible, since there was no uranium, no thorium present? It is always at critical moments, such as these, that such paradoxes become most exciting for the creative mind. This is what drove Marie to leap boldly onto an hypothesis taking shape in her mind.

It therefore appeared probable that if pitchblende, chalcolite, and autunite possess so great a degree of activity, these substances contain a small quantity of a strongly radioactive body, differing from uranium and thorium and the simple bodies actually known. I thought that if this were indeed the case, I might hope to extract this substance from the ore by the ordinary methods of chemical analysis [Curie 1961 (1903), p. 16].

Pitchblende is composed of almost 30 elements, and present in this elemental curry, is an extremely powerful radioactive source in a very minute part. How little it actually was, however, would astonish not only the Curies but the whole world. Marie and Pierre initially thought that it could be about 1 percent of the pitchblende. At the end of almost four years, they found that it was less than 1/1,000,000th of 1 percent.

Marie Curie, the scientist, is unlike most any other of her time—and now. Her mind worked like a true Platonic scientist. She was an experimental scientist, who believed first in the primacy of ideas. In January 1904, just after she, Pierre, and Henri Becquerel had won the Nobel Prize for Physics in November 1903, the American Century Magazine published an article by her, which leaves no room for doubt of her genius for hypothesis formation, and her rigor for experimental proof.

The discovery of the phenomena of radioactivity adds a new group to the great number of invisible radiations now known, and once more we are forced to recognize how limited is our direct perception of the world which surrounds us, and how numerous and varied may be the phenomena which we pass without a suspicion of their existence until the day when a fortunate hazard reveals them. . . .

[Electromagnetic radiations] . . . are present in the space around us whenever an electric phenomenon is produced, especially a lightning discharge. Their presence may be established by the use of special apparatus, and here again the testimony of our senses appears only in an indirect manner. . . [Century Magazine, 1904, emphasis added].

Towards the end of the article, she presents the world with the fruits of their labor, which began in the winter of 1897, and continued unrelentingly to the day of the article. Although a few other scientists, namely Sir Ernest Rutherford, also knew and understood this newly discovered phenomenon, she would be the major spokesman, for her discoveries of radium, polonium, and actinium (the latter with the help of fellow scientist, André Debierne). All three elements were found in more than 4 tons of pitchblende.

If we assume that radium contains a supply of energy which it gives out little by little, we are led to believe that this body does not remain unchanged, as it appears to, but that it undergoes an extremely slow change. Several reasons speak in favor of this view. First, the emission of heat, which makes it seem probable that a chemical reaction is taking place in the radium. But this is no ordinary chemical reaction, affecting the combination of atoms in the molecule. No chemical reaction can explain the emission of heat due to radium. Furthermore, radioactivity is a property of the atom of radium; if, then, it is due to a transformation, this transformation must take place in the atom itself. Consequently, from this point of view, the atom of radium would be in a process of evolution, and we should be forced to abandon the theory of the invariability of atoms, which is the foundation of modern chemistry [M. Curie 1904].

In the years before this paper was written, Marie and Pierre had an enormous amount of work to do. First, they wrote to the mine that produced the most active pitchblende that they tested, which belonged to the Government of Austria at Joachimsthal in Bohemia. They were given their first ton of discarded material, and paid the cost of shipping.

On May 20, 1921, the East Room of the White House was filled with more than 100 important scientists and diplomats from Poland and France. U.S. President Warren Harding had the honor of presenting Marie Sklodowska Curie with a key inscribed with the following words: “From the Women of America” to Madame Marie Curie. The elaborate key was to open a ribbon-draped cabinet, which contained one gram of radium, worth more than $100,000, which was paid for by America’s women. His inspiring speech paid great homage to Madam Curie, and expressed profound respect for both her adopted nation, France, and the newly re-created nation of Poland, the land of her birth, which had finally become an independent nation again, after the war:

On behalf of the American nation, I greet you and welcome you to our country, in which you will everywhere find the most cordial possible reception. We welcome you as an adopted daughter of France, our earliest supporter among the great nations. We greet you as a native-born daughter of Poland; newest, as it is also among nations, and always bound by ties of closest sympathy to our own Republic. In you we see the representative of Poland restored and reinstated to its rightful place, of France valiantly maintained in the high estate which has ever been its right.

We greet you as foremost among scientists in the age of science, as leader among women in the generation which sees woman come tardily into her own. We greet you as an exemplar of liberty's victories in the generation wherein liberty has won her crown of glory. In doing honor to you we testify anew our pride in the ancient friendships which have bound us to both the country of your adoption and that of your nativity.

It has been your fortune, Madam Curie, to accomplish an immortal work for humanity. We bring to you the meed of honor which is due to pre-eminence in science, scholarship, research, and humanitarianism. But with it all we bring something more. We lay at your feet the testimony of that love which all the generations of men have been wont to bestow upon the noble woman, the unselfish wife, the devoted mother. If, indeed, these simpler and commoner relations of life could not keep you from attainments in the realms of science and intellect, it is also true that the zeal, ambition and unswerving purpose of a lofty career could not bar you from splendidly doing all the plain but worthy tasks which fall to every woman's lot.

A number of years ago, a reader of one of your earlier works on radioactive substances noted the observation that there was much divergence of opinion as to whether the energy of radioactive substances is created within those substances themselves, or is gathered to them from outside sources and then diffused from them. The question suggested an answer which is doubtless hopelessly unscientific. I have liked to believe in an analogy between the spiritual and the physical world. I have been very sure that that which I may call the radioactive soul, or spirit, or intellect—call it what you choose—must first gather to itself, from its surroundings, the power that it afterwards radiates in beneficence to those near it. I believe it is the sum of many inspirations, borne in on great souls, which enables them to warm, to scintillate, to radiate, to illumine, and serve those about them.

Let me press the analogy a little further. The world today is appealing to its statesmen, its sociologists, its humanitarians, and its religious leaders for solution of appalling problems. I want to hope that the power and universality of that appeal will inspire strong, devout, consecrated men and women to seek out the solution, and, in the light of their wisdom, to carry it to all mankind. I have faith to believe that precisely that will happen; and in your own career of fine achievement I find heartening justification for my faith.

In testimony of the affection of the American people, of their confidence in your scientific work, and of their earnest wish that your genius and energy may receive all encouragement to carry forward your efforts for the advance of science and conquest of disease, I have been commissioned to present to you this little phial of radium. To you we owe our knowledge and possession of it, and so to you we give it, confident that in your possession it will be the means further to unveil the fascinating secrets of nature, to widen the field of useful knowledge, to alleviate suffering among the children of man. It betokens the affection of one great people to another [The New York Times, May 21, 1921].

After President Harding's speech, Madame Marie Sklodowska Curie responded:

I cannot express to you the emotion which fills my heart in this moment. You, the chief of this great Republic of the United States, honor me as no woman has ever been honored in America before. The destiny of a nation whose women can do what your countrywomen do today through you, Mr. President, is sure and safe. It gives me confidence in the destiny of democracy. I accept this rare gift, Mr. President, with the hope that I may make it serve mankind. I thank your countrywomen in the name of France. I thank them in the name of humanity which we all wish so much to make happier. I love you all, my American friends, very much (Science 1921, p. 497).

The trip to the United States was a momentous occasion, not only for Marie Curie, but for the American people themselves. The hospitality and generosity shown to Madam Curie went far beyond a simple fund-raising campaign. In each place she visited, from New York City, to Buffalo, to Chicago, and many other cities, the American people treated her with a respect and dignity usually reserved for heads of state. In some ways, the campaign to raise money to buy Marie Curie a gram of radium, was similar to the great fund-raising campaign in America to build a base for the Statue of Liberty, a gift given by the French nation.

The person responsible for orchestrating this "event," which took Marie all over America to be honored, was an American editor of a popular woman's magazine, The Delineator. The woman was a small, dynamic individual named Marie Mattingly Meloney, who wanted everyone to call her "Missy."

Missy had a somewhat unique background. Her father was a doctor, and her mother, his third wife, taught newly freed black slaves in the South. The Delineator featured the latest women's fashion, and articles on how to take care of home and family. Missy had tried unsuccessfully, for quite some time, to get a story on Marie Curie, but every time she sent a journalist to Paris, Marie refused to see him. Marie Curie had no use for the media, and had viewed them disdainfully ever since the early days of her discovery of new radioactive elements. Many had tried to penetrate the private life of Marie and Pierre. None had been permitted to speak with her.

In mid-1920, Missy traveled to Paris, determined to speak with Madam Curie herself. Missy was not one to take "no" for an answer, but that was the first answer she got. Undeterred, Missy visited the French author Henri-Pierre Roche (the author of the novel Jules et Jim), and asked him to intercede to get Marie to talk to her. Roche was impressed by Missy's genuine enthusiasm, and thought that it would be important for Marie to meet her. Marie agreed to talk to her for a few minutes only, and that encounter led to their life-long friendship.

When Missy asked Marie what she could do to "help" her, Marie told her that she had no radium to experiment with. After the end of the war, France was depleted of both manpower and money. Although the Radium Institute was built, there was no money forthcoming to equip it properly. The radium which Marie had safe-guarded in Bordeaux during the war was all that France had—1 gram—and that was used, primarily, in the biological section to provide radon tubes for cancer therapy. Marie told Missy that the United States had the world's most plentiful supply, 50 grams.

Missy immediately began to think about what a great good it would be for America to give one of those grams to Marie, and she calculated the cost at about $100,000 per gram (in 1920 dollars). She saw an opportunity before her: Instead of simply getting a "story" for her magazine, she would use her influence, contacts, and clout in a noble cause: The women of America would give Marie Curie a gram of radium. She wanted Marie's plight to generate a response from the American people, and went back to the United States to start the campaign. Initially, however, she thought she might be able to raise $10,000 each from 10 women, but soon discovered that was impossible.

Missy herself became the chairman of the "Marie Curie Radium Fund," and she contacted prominent medical people in New York to ask them to become part of the board. She discovered that she had no problem getting help from American doctors. Marie Curie's name was highly respected among the medical profession in the United States. During the war, Marie had single-handedly educated scores of U.S. physicians at the Radium Institute in X-ray technology, and had enjoyed the Americans' "brash" sense of "we can do anything" that Americans were so famous for at the time.

One of the doctors who immediately joined the board, Robert Abbe, had been experimenting, and using radium therapy for years. He had visited the Curies as early as 1902 in Paris, and had been the first American doctor to use radium in treating cancer and other diseases. Although radiation therapy was still in its infancy, by the year 1920, the year of Missy's visit to Paris, it held out promising hopes to millions of people worldwide.

Other prominent men and women were recruited to sit on the board, including Mrs. John D. Rockefeller, Mrs. Calvin Coolidge, Mrs. Robert Mead (the founder of the American Society for the Control of Cancer), and other women with time and money. The advisory committee of scientists included the President of the American Medical Association, and leading representatives from the Rockefeller Foundation, and Harvard, Cornell, and Columbia universities.

Missy used the pages of The Delineator as the public solicitor to encourage American women to give what money they had. Young college women took up collections to give to the fund, as did little girls who found out about the campaign, sending in their nickels and dimes. Marie Curie had been receiving letters from all over America for many years from cancer sufferers, who had had their cancer "cured" by enterprising doctors, like Dr. Abbe. One woman, the first to be treated at the hospital in Gettysburg, Pennsylvania, wrote to Marie about her radium treatment: "What it done for me none but God can tell."

Madam Curie received letters like this all the time; she was always moved by what people said to her, and she answered the letters when she could.

Perhaps the finest expression of appreciation to Marie Curie, however, was from the American doctors. Those on the board took it as their personal responsibility to ensure that the campaign to raise the $100,000 was more than a success. They wanted not only to buy the gram of radium, but also to ensure that Madam Curie had a modern, well-equipped laboratory. In each city where Marie Curie was to visit, a fund-raising quota-system was set up: New York had a quota of $10,000; Boston and Philadelphia each had a quota of $5,000. Each doctor on the board participated. Dr. Abbe, for example, wrote to Dr. John G. Clark of Philadelphia (both of them were members of the prestigious Philadelphia College of Physicians): "I have by personal appeal to my patients raised over 20,000 dollars myself. . . ."

Re-creating the Curie Experiment to Measure Radioactivity

My understanding of Curie's work grew enormously, because I simply 'loved' trying to understand that which she discovered." Author Denise Ham with Paul Frelich, who helped her build this capacitor/electrometer hookup for measuring the radioactive emission from the americium in a smoke detector. (Roger Ham)

I asked Paul Frelich, a retired electrical engineer, to work with me to re-create the Curie experiment. Originally, I had hoped we could create the exact experiment used by the Curies, but we had to abandon this idea because of the high cost of quartz. Mr. Frelich was kind enough to think through the problem, and create his own version of the Curie experiment, which readers can try. Here is Paul's summary:
The experiment requires the following equipment: (1) Sample holder, (2) Electrometer, (3) Radioactive source, and (4) Power supply.

(1) The sample holder is a neutralizing capacitor that is used in vacuum tube amplifiers. Two circular plates, each 23x16 inch in diameter, are held parallel to each other on ceramic insulators. They can be mounted with the plates either horizontally or vertically oriented, and the spacing between the plates can be varied. One plate is fixed in the assembly, and the other fixed to the end of a long screw, which allows the spacing to be varied from zero to 15x16 of an inch.

In the sample holder shown here, the plates are mounted horizontally. The fixed bottom plate holds the sample, and the upper plate, adjustable in spacing, goes to one pole of the electrometer. A variable potential is applied to the bottom plate.
This neutralizing capacitor assembly is mounted inside a large coffee can, 61x16 inch in diameter by 61x8 inch high. The can is fitted with a door so that samples can be placed on the bottom capacitor plate.

Close-up of the homemade neutralizing capacitor assembly built inside a coffee can. The sample is placed between the two parallel plates. (Roger Ham)

The purpose of the can is to act as a shield against power line hum, TV, and AM/FM stations, weather radars, and so on. The can is the zero potential reference.

(2) The electrometer is a commercial instrument, Keithley Model No. 260 B, capable of measuring very high resistances and very, very low currents. A shielded cable connects the top plate of the sample holder to the electrometer.

(3) Radioactive source. A smoke-detector was disassembled to obtain the americium, which is rated as a 10-microcurie source. It seems to be a very thin layer or film on a ring: 1x4 inch in diameter by 1x8 inch thick with a 1x8 inch hole in the center containing a rivet, which was used to hold it in the smoke detector. Only the top thin layer is radioactive; the other material is not.

I also selected some samples of granite from a gravel pile at a local construction site, and some samples from an unpaved roadway on a farm in Vermont. Some of these showed radioactivity, and some did not. One sample showed a strong pulsing activity.

(4) Power supply. We originally used a power supply that provided voltages of 0, 10, 25, 75, 300, and 460 volts DC, but this was too heavy to carry around and was dangerous to use at the higher potentials. So, I designed a battery supply that provided 0, and + or – 1.5, 4.5, 9.0, 13.5, and 22.5 volts.

Marie & Pierre Curie, Panama 1939, 1940

Who was Florence Stoney (1870-1932)?

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I was contacted in early October 2002 by Clare Critchley, a researcher for Woman's Hour, to ask if I would be interviewed by Jenni Murray about Dr Florence Stoney. Florence Stoney was the first female radiologist in the UK and has been almost completely forgotten. She was born in 1870 and grew up in Dublin being educated at home and at the Royal College of Science. At that time, she could not study medicine at Dublin University, medical degrees in Ireland not then being open to women. She therefore came to England, attending the London School of Medicine for Women and the Royal Free Hospital, graduating MB BS in 1895 with honours. She received the prize for the best student in her year. She obtained her MD in 1898.

Her father, Dr Johnstone Stoney, supported the higher education of women and saw no reason why women should not be suited for Medicine, Law and even the Church. Her sister was Edith Stoney the physicist. Edith Stoney served in France during the Great War in the Scottish Women's Hospital at Royaumont.

In 1902, Florence Stoney started the X-ray work at the Royal Free Hospital and New Hospital for Women (Elizabeth Garrett Anderson Hospital) and was demonstrator in anatomy at the London School of Medicine for Women. She set up the X-ray departments when the apparatus was still very primitive; the rooms were badly ventilated with no separate room for X-ray work. She often took the plates home and developed then in her bathroom in the evenings. No assistant was provided and she did all the work herself. At that time, the radiologist was not a member of the hospital Medical Staff and she was not a member of the committee that discussed the work of X-ray department.

On August 4th 1914, the first day of the Great War, Florence and Edith Stoney offered their services to the British Red Cross at the War Office in London. By this time, she had 13 years experience in radiology. Her offer was refused because she was a woman by Sir Frederick Treeves (of Elephant Man fame). Florence and her sister had a complete X-ray installation prepared and all ready to use. Florence was undaunted. She “wasted no time with arguments or indignation” and joined the author Mrs. St. Clair Stobart in organizing a voluntary women’s unit. This unit was established with the Belgian Red Cross and consisted of 100 (later 135) beds, 6 women doctors, 10 trained nurses and female orderlies. Florence organized the medical part of the surgical unit entirely staffed by women. They initially went to Brussels and were turned back. However, in September 1914, they went to Antwerp and set up their all woman’s hospital described as “a model of organization.” The unit saw many casualties straight from the trenches. In October 8th 1914 the unit was under shellfire for 18 hours. They evacuated their patients and then started to walk to Holland. They were picked up be three London buses and sat on ammunition cases! Florence was later awarded a medal: the 1914 Star. Florence continued work in France at Château Tourlaville near Cherbourg. Water, sanitation and electricity had to be arranged. The X-ray equipment was primitive and there were many difficulties

In March 1915 she was one of five women doctors accepted for full-time work by the War Office and was appointed to run the radiology department of the Fulham Military Hospital. This hospital had over 1000 beds and she examined over 15000 cases. Her work – particularly concerned with localization of bullets and her knowledge of anatomy greatly helped the surgeons. She also was able to identify the presence of sequestra (dead bone) and the removal of this aided the treatment of these injuries. She was awarded OBE after the war.

Her health was damaged by the war, in part related to over-exposure to radiation. She was seen to have X-ray dermatitis of her left hand. Florence moved to Bournemouth where she was on the staff of two hospitals. She retired in 1928 and died in 1932. She had a “gentle kindness and rich sympathy for suffering – showed courage in her own last, long and painful illness.”

Florence Stoney had a firm faith in the potential capacity of women to fill positions of the highest responsibility. She felt that women should develop their powers to the highest possible extent and then, if opportunity failed them, they should make their own opportunity. She was a keen constitutional Suffragist (Suffragette) and she took part in many demonstrations and processions. In personality she was shy and retiring with a quiet manner. This was combined with an iron will and undaunted courage. Her gentle graciousness disarmed opposition and gained cooperation “few had dreamt of the ardour existing beneath that demure and gentle exterior.” In professional matters she was very keen to pass on all that she learnt. She was innovative in her approach to radiology and was involved in many early X-ray developments. She had the second Coolidge tube (the early modern-type X-ray tube) in the country.

Florence Stoney was concerned with women's health issues such as the treatment of fibroids and the diagnosis of pelvic deformities in women due to osteomalacia that would cause problems in childbirth. In retirement, she traveled in India to investigate the condition and it was the subject of her last scientific paper.

Her obituary appeared in the British Journal of Radiology in 1932. It covered five pages and contained many warm personal testimonials. She was a remarkable woman and we should remember her with gratitude for her pioneering work in our specialty.

(Previously appearing in BIR News)

"GAS" VERSUS HOT CATHODE X-RAY TUBES IN THE U.K.

By D.R.Guttery

A.C.Cossor is generally considered to have been the first "dedicated" X-ray tube maker in Britain. He had established himself as a scientific glass blower in about 1891 and by the time the discovery of X-rays was announced in the London *DAILY CHRONICLE* newspaper on January 6 1896 was already a well-respected maker of Crookes and similar gas-discharge tubes and thus ideally equipped to meet the demands of the many experimentalist who rushed to obtain apparatus to replicate Röntgen's experiments. Other British scientific glass blowers with experience of manufacturing gas-discharge tubes and possessed of the relatively simple skills needed to make the early two-electrode "focus" X-ray tubes were A.E.Dean, James J.Hicks, Louis P.Casella and H.Helm[i]. Hicks and Casella soon disappeared from the X-ray scene leaving Cossor, Dean and Helm – together with a newcomer, G.C.Aimer – as the sole British tubemakers until 1906 when Newton & Co. started making tube following its move from No.3 Fleet-street to a larger factory at 41--3 Hornsey-road. Aimer had established a small tubemaking company in 1903 after learning the craft of glassblowing at Dean's. A further London-based source of tubes was created in 1910 when Cuthbert Andrews set up a small workshop at 35 Hatton Garden to assemble some of the range of X-ray tubes made in Hamburg by C.H.F.Müller. By 1914, many of the Müller designs were "entirely made in London". Virtually none of the British makers was known outside Britain apart from Cossor whose company progressed to making many other products including wireless valves, cathode ray tubes, oscilloscopes, experiment apparatus for Marconi and miniature lamps for cystoscopes and endoscopes. Several of the early British tubemakers sustained serious radiation injury – A.E.Dean, H.J.B. Aimer (G.C.Aimer's brother) and Cossor's workshop manager, William Underhill Hilliar are all commemorated on the Martyrs' Memorial in Hamburg.

The first British makers soon discovered that the home-produced lead or flint glass that many of them had previously used for scientific glassblowing was not suitable for X-ray tube envelopes and were obliged to import suitable "soda" glass from France, Belgium and (mainly) Germany. Their dependence on imported glass was to cause problems later.[ii]

From 1897, many of the tubes used by British equipment manufactures and suppliers like Newton & Co., Watson & Son, Harry W.Cox and Karl Schall (one of the original partners of Siemens, Gebbert & Schall of Erlangen but in business in London on his own account since 1887) were imported from Germany. In fact, it was admitted at the time that German-made tubes more or less dominated the U.K. market until the 1914 War. Respected German makers were C.H.F.Müller, Emil Gundelach and Mylius Ehrhardt but many of the other continental makers listed in Rønne and Nielsen's *Development of the Ion X ray Tube* never came to Britain. Imported tubes often bore the U.K. importer's paper label or glass-etched trademark making it difficult today to identify the original manufacturer. For example, Cox's "Record" and Watson's "Penetrator" were almost certainly manufactured by C.H.F.Müller in Hamburg. A Müller design submitted by Cox was awarded the Röntgen Society's [now B.I.R.] President's Gold Medal in 1901 for the best practical X-ray tube. Twenty-eight different *models* of tube were submitted for the competition of which five were of British manufacture and eight American, while fifteen came from German makers thus confirming their strong position in the U.K. market.

The equipment maker Newton & Co. [from 1914 named Newton & Wright] started to produce its own tubes in 1906 and at the same time also became sole U.K. agents for the American tube company Macalaster-Wiggin. Eventually, Newton discontinued its own designs to concentrate on making the sophisticated Macalister-Wiggin designs under licence.

Named French tube makers do not seem to have penetrated the British market in any quantity until the 1920's and were then virtually limited to a single company — Henri Pillon of Asnières.

As has been stated earlier, in 1909, C.H.Müller of Hamburg commissioned Cuthbert Andrews to establish a small workshop to assemble and evacuate X-ray tubes in London using electrodes and glass bulbs supplied from Germany. Andrews was provided with an advance of £100 to purchase workshop equipment and Müller sent over three Hamburg glassblowers to train the British workers. The original workshop in the basement of 35 Hatton Garden was opened in July 1910. Andrews immediately Anglicised the name "Muller" by deleting the diacritical mark or umlaut from the "ü" and within three years many of the tubes were "entirely made in England" as announced in the company's first London catalogue published in January 1914 – seven months before declaration of war with Germany. The glass bulbs were also etch-marked to show the tubes' British origin.[iii]

Considerable interest was aroused with the announcement of Coolidge's invention of the hot cathode tube in the *Times* newspaper on 31 December 1913 and technical accounts of the new design were soon widely reported in the British medical and technical press. Commercial examples of the tube were not available until about March 1915. The U.K.

outlet and owner of the British patent was the British Thomson-Houston Company (the X-ray part of which was absorbed by equipment maker Watson & Co. in 1927). The majority of British equipment at the time was still based on the induction coil. Initially, the 12-volt supply for the Coolidge filament had to be obtained either from a secondary (accumulator) battery standing on an insulated table or wall bracket or – in those parts of the country where an A.C. mains supply was available – from an insulated step-down transformer. Many British radiologists continued using induction coil equipment until the late 1920's as the "Snook" or closed-circuit high-voltage transformer first introduced to the U.K. from Philadelphia in 1908 had not met with the rapid acceptance that it achieved in America, Germany and certain other countries. Apart from a natural conservatism, another reason for retaining the induction coil could have been that many parts of Britain had a D.C. mains supply requiring the additional purchase of an alternator to operate equipment fitted with closed-circuit transformers.[iv]

Many users of the early Coolidge "Universal" tubes were disappointed with the poor diagnostic image definition resulting from the "extra-focal" radiation emitted by the unhooded one-piece tungsten anode. Even as late as 1922, Schall's equipment catalogue *X-ray Apparatus and their Management* comments –

> Coolidge tubes cannot yet be made with a fine focus. They can be used for showing fractures of legs or arms, and foreign bodies like rifle bullets; but for producing negatives with fine detail, gas tubes with a sharp focus are infinitely better.

A similar – although prejudiced – comment about the early Coolidge tubes is made in Cuthbert Andrews privately printed Address *Cats and Kittens Radiography* to the Society of Radiographers in 1926: " . . . its lack of focus, and its production of scattered or secondary radiation."

For a number of years, the main application for the Coolidge tube was X-ray therapy where the significantly greater output and higher stability justified the cost of either modifying existing generating equipment or designing new high-voltage generators incorporating a filament-heating system. The poor definition must have deterred diagnostic users in other countries too.

The German Lilienfeld hot-cathode tube of the same period as the Coolidge never came to Britain because it was too expensive and too complicated and also because it's importation could have resulted in patent litigation.

Declaration of war meant that almost the entire supply of X-ray tubes was diverted to military applications and led to serious shortages for civilian use[v]. The non-availability of suitable glass for tube envelopes presented an immediate problem to British tube makers and obliged the Secretary of State for War to establish various technical committees to sponsor experimental work developing formulae for the special glasses used for X-ray tubes, miners' safety lamps, chemical apparatus, thermometers and various other specialist products – all of which had formerly been imported.[vi] The general shortage of tubes was worsened by the lack of imports[vii]. Müller's small London workshop was immediately confiscated by the Custodian of Enemy Property but Cuthbert Andrews continued as manager. Andrews was allowed to purchase the company from the Custodian in 1915 (for £200) and from then on made tubes on his own account. He also retained the three highly-skilled Hamburg glassblowers throughout the duration of the war as they had not been quick enough to return to Germany in 1914. They were never interned as they were too important helping the war effort and, in fact, two of them were still working for Andrews during the Second World War.

When the war ended, the only British companies still making X-ray tubes were A.C.Cossor, Newton & Wright, A.E.Dean, G.C.Aimer and Cuthbert Andrews. The Americans were represented by Machlett (who had first come into the country during the war), G.E.Coolidge (by then, manufactured under licence by B.T.H.) and Macalister-Wiggin.

Andrews had experimented making a hot cathode tube as early as 1914 (in conjunction with the physicist C.L.Lindemann) but realised that it was too crude to be successful. When he reconsidered the idea after the war ended, he was faced with two obstacles –

> . . . first, the virtual impossibility of obtaining certain essential materials; and second, the existence of a patent, which, we were advised on high legal authority, was unassailable. We were, therefore, reduced to the necessity of looking forward to the expiration of the patent in 1927, meanwhile carrying on experimental work with the object of discovering an alternative basic principle – an apparently hopeless task. Then came the 'war extension' of patent validity, which added a further two years' life to the patent in question, bringing the date of expiration to [June] 1929 . . .

Andrews and his British-based competitors therefore had no alternative but to continue the profitable but slowly declining business of producing "gas" tubes. In May 1921, Andrews introduced the *LEVIATHAN,* a completely new design of heavy anode gas tube in 7-inch and 8-inch versions which he claimed was the "best X-ray tube which has ever been constructed in this or any other country". The *LEVIATHAN* was very successful and continued in production until about 1929-30. The fact that Andrews made or repaired a combined total of nearly 1500 (mainly 8-inch/200 mm.) gas tubes during 1922 gives some indication of the continuing demand. The "Buy British" policy actively promoted by Andrews in his advertisements combined with his close personal contact with the radiological world during the following three decades also greatly assisted the success of his products.

The Cambridge D.M.R.E. examination for radiologists still included questions about gas tube operation as late as 1925 and, in May, 1927, the Society of Radiographers debated a motion that

> . . . the hot cathode tube is not always conducive to the best radiographic results; and that to allow the gas tube to be entirely superseded by the hot cathode tube would be definitely injurious to the interests of radiography."

> The debate is reported in full in ten closely printed pages of the Society's *JOURNAL*. Although several speakers at the debate condemned the "gas" tube as an antique instrument, the report concludes – "There seems to be a general feeling that results with gas tubes were better.

A vote taken at the end of the debate resulted in a majority in favour of the motion supporting the gas tube.

Those people who had condemned the gas tube at the debate were criticised by Stanley Melville – one of the leading pioneers of British radiology – in a letter that he wrote to the *British Journal of Radiology* ending –

> In chest work particularly, I am certain that the gas tube has not its equal, and it is an interesting fact that, in this, I am supported by no less authorities than the American writers, Wesseler and Jaches, in their standard work on Chest Radiography. The work of the Radiologist is diagnosis, rather than the making of pretty pictures.

The debate also seems to have been the inspiration for a half-page Newton & Wright advertisement in the April 1927 issue of *B.J.R.* promoting its famous *HERCULES* gas tube with the statement –

> The controversy as to the merits of 'Gas' or 'Hot Cathode" Tubes has not yet been settled, the truth being that both have their advantages and both have their drawbacks.

In a January 1928 review of the annual Exhibition of X-ray apparatus held in Westminster at which G.C.Aimer and Cuthbert Andrews showed various models of "gas" tubes, the writer comments that it would "serve to reassure those workers who have been inclined to lament prematurely [their] demise." In October of the same year, Karl Schall's son, William, following a visit to the International Congress at Stockholm wrote about the situation in Britain –

> . . . the design of apparatus has been severely hampered by the Coolidge patents. These established a veritable monopoly which kept the coil and gas tube alive beyond their natural span, and prevented that development of hot cathode tube design which has so obviously resulted from the conditions of healthy competition in Germany.

In July 1929, B.T.H. applied for a further extension to the Coolidge patent but on the basis of vigorous opposition from Newton & Co., A.E.Dean and Cuthbert Andrews – backed by moral and material support from large numbers of radiological workers – the Chancery Court agreed an extension of only one more year (*ELECTRICAL REVIEW,* 2 August, 1929, p.201)

Meanwhile, five years earlier, in 1924, Andrews had became aware of the work done by Dr Bouwers of Philips Lamp Works developing a hot cathode self-protected or radiation-shielded "low vacuum" tube – the *METALIX* – and this turned his attention to the development of a similar tube radically different from the original Coolidge type and thus a way of overcoming the patent problem. The first Philips *METALIX* tube was installed in St.Bartholomew's Hospital in mid-1924 and thereafter extensively advertised in the radiological press and by 1926 was included in the catalogues of most of the equipment suppliers especially after the range was extended to include the Goetze line-focus. Siemens (S.R.W.) introduced its equivalent self-protected *MULTIX* tube to London in July 1930 although it had been available in Germany since 1926. By 1927 Andrews' own hot-cathode, self-protected *PROTEXRAY* tube had begun to take practical form and in May, 1929 he was able to show a completed example at the British Institute of Radiology. By June, 1930 it was in regular production and fully protected by patents. The designer was Andrews cousin, J.D.Frye.

So far as Britain was concerned, successive introduction of the Philips *METALIX*, Siemens *MULTIX* and Andrews *PROTEXRAY* tubes during the second half of the 1920's decade finally signalled the beginnings of the end of the gas tube and induction coil era and by 1930 only the smaller hospitals and private practitioners were still so equipped. It was also during about 1929-30 that A.C.Cossor, Newton & Wright and A.G.Aimer finally ceased X-ray tube production. A.E.Dean had ceased in about 1927. None of them had the inclination or – apart from Cossor – the technical resources to undertake the development of a hot-cathode tube. From then on, Andrews was the sole remaining X-ray tube maker in the British Empire and when he ceased manufacture in 1946 could boast of having produced a combined total of more than 30,000 ionic and hot-cathode tubes of 75 different ratings during his long X-ray career, commencing 1909.

These hurried notes are have quite a few loose ends, but I think I've correctly indicated what happened with the development of tubes in the U.K. between 1896 and 1930 and why the "gas" version persisted for so long.

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[i] It is possible that H.Helm of 66 Hatton Garden, London was from the same family as the tube designer Otto Helm of Könisberg mentioned at pp.107 and 200 of Rønne and Nielsen's *Development of the Ion X ray Tube.* He was still offering his range of *SIRIUS* air and water-cooled iridium anode tubes as late as 1918.

[ii] "It has been stated that German-made Crookes' tubes are superior to British because the latter are made of lead glass which is comparatively opaque to the "X" rays. A.C.Cossor, who has made many of the tubes now in successful use, says that although lead glass has been used for most of the old tubes for Crookes' radiant matter experiments, all made for Röntgen work have been of the same glass as is used by the Germans; but infinitely thinner than most of the German lamps. No doubt other British glass-blowers have taken the same precaution." – *THE PHOTOGRAM* , March, 1896, p.79.

A uniquely British problem. The use of lead oxide as a flux had been a feature of British glassmaking since its successful introduction by George Ravenscroft during the late 17th century and was – and still is – the reason for its unique crystal-like brilliance.

[iii] Müller's London branch may have been established to protect its patents following the introduction of Lloyd-George's Patents Act of 1907 despite the fact that each of Müller's patent applications registered in Britain up to 1914 was subsequently abandoned.

[iv] An example of the conservatism of the period is illustrated by a Canadian-based radiologist's recollection of a visit to Thurstan Holland's department in Liverpool in 1910. Thurstan Holland was one of the pioneer architects of British radiology and was then using an X-ray apparatus energised by a 12-inch induction coil:

"I saw some beautiful radiographs by Mr Thurstan Holland who showed me his apparatus. He got beautiful radiographs, but had to expose quite a long time. I said I was using a four kilowatt transformer. He asked why. I said that there was no reason, except that I got the pictures more quickly. He said that he did not need to get them more quickly." – Lieut.-Colonel Robert Wilson, Canadian Army Medical Corps, reported in *Journal of the Röntgen Society*, October 1917, p.98.

[v] Editorial [by W.Deane Butcher] in the October 1914 of the *ARCHIVES OF THE ROENTGEN RAY* (XIX, 159-160:

"THE SHORTAGE IN X-RAY TUBES. One of the minor complications of this terrible war is a threatened shortage of X-ray tubes. For many years past we have insisted, in season and out of season, on the desirability of being entirely independent of the Continent for our supply of X-ray material. and representations have been made to Parliament and the Government, but witout success.

"At the present moment the case stands thus:– There are, in England, some three or four manufactures of X-ray tubes, but these depend almost entirely on Germany for the supply of the soda glass required for their construction, and the same may be said of the American focus-tube makers, from whom it was hoped we might obtain an additional supply.

"At the present moment we must get our X-ray tubes where we can, and we need not enquire too closely as to the exact nationality of those who may be able tp manufacture an X-ray bulb in England".

[vi] With the exception of a very few outstanding companies, the British glass industry was then in a particularly parlous, depressed and disorganised condition. The methods of manufacture were mystical, secret, traditional and empirical. Scientists were seldom employed, silicate chemistry was not understood, and rule of thumb prevailed. The composition of glass was a precious secret handed down from father to son. Foreign manufacturers enjoyed cheaper raw material, cheaper labour, Government subsidies and tariff protection. –

"The unfortunate condition of the glass trade was attributed by men of science to ignorance and want of initiative on the part of the manufacturer, but by the manufacturer it was attributed to free trade, unfair trading conditions, and to the gulf dividing industrial from academic chemistry...

" . . . French and German soda glass could be purchased at 3¾ pence per pound [£0.0035 per kilo.] [before 1914] . . .

"In justice to the English manufacturers it must be remembered that the German and Austrian furnaces and pots were and are adapted for melting a leadless glass, whereas the English furnaces and pots were adapted for melting a glass containing lead . . . " – H.J.Powell *Glassmaking in England* (1923) chapter XV: "Glassmaking during the War, 1914-18"

"There was a desire amongst manufacturers everywhere for closer association with one another and for contact with science and men of science, by which means alone the deadening influences of generations past could be overcome . . . " – Opening address at the inaugural meeting of the Society of Glass Technology, November 9, 1916.

[vii] The shortage of tubes appears to have persisted throughout the War and orders placed with suppliers for tubes for civilian use were subject to the *Glass Control (Consolidated) Order 1917* and had to be approved and certified by the Ministry of Munitions of War, optical and glassware supply, 22-23 Hertford-street, London. W1.

Gas (ion) Tube