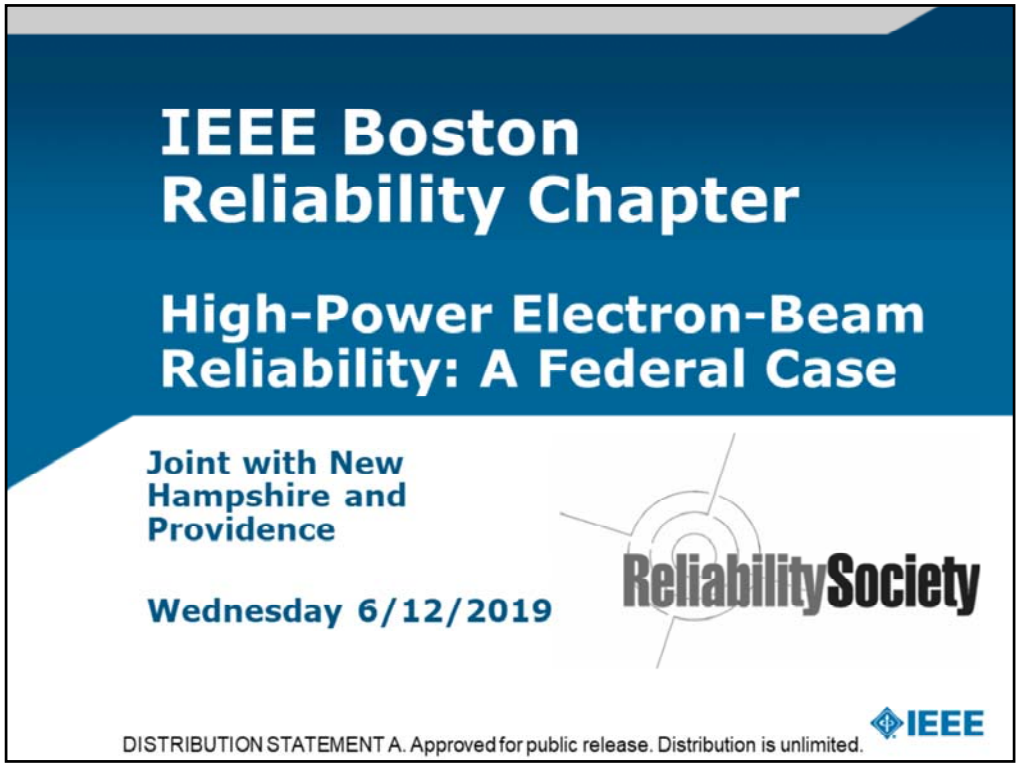

Reliability of High-Power Electron-Beam Accelerators: A Federal Case

This presentation is about work that I did from 1997 through 2002, before I started working at the Lab in 2009.

djw

5/30/2019

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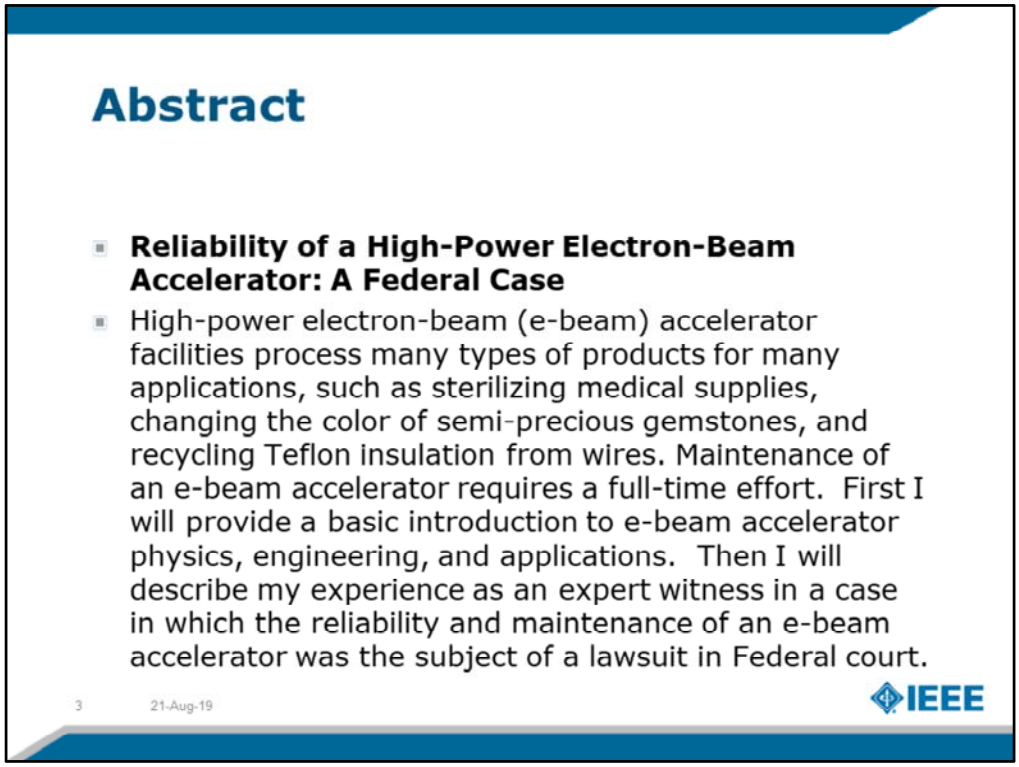
How would a lawyer find an expert?

More than 90% of lawsuits are settled—here's one where a trial started

I now think that the legal process is actually excellent, better than I thought



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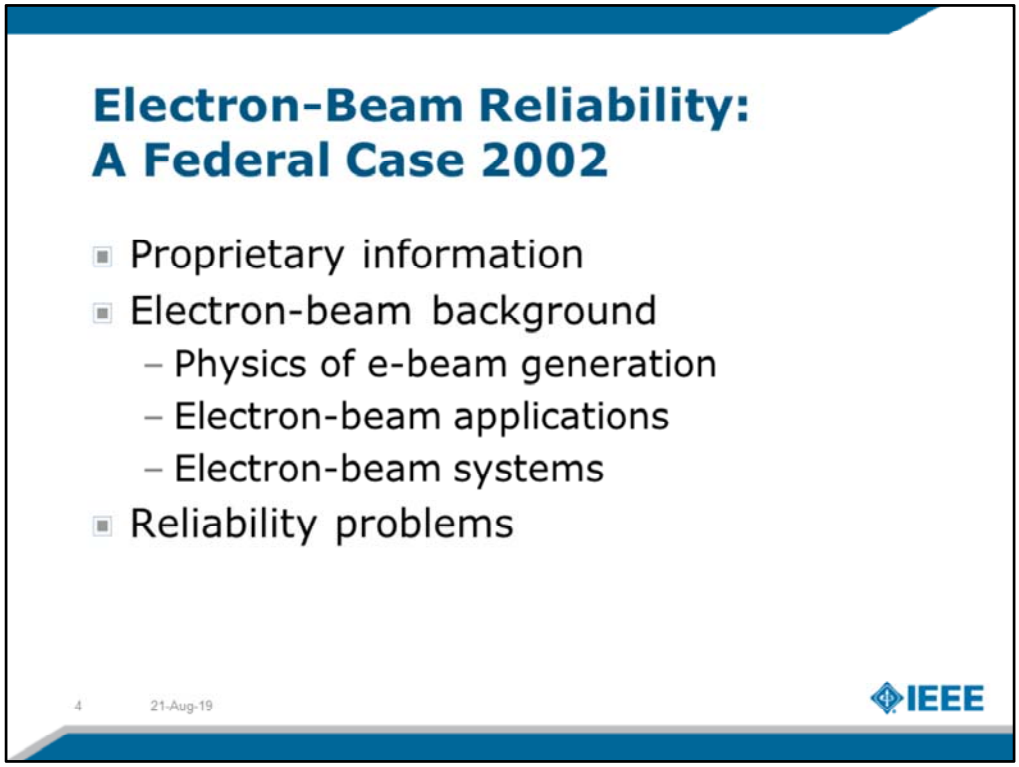

Proprietary information:

It's now been about 17 years since this case (This presentation is about work that I did from 1997 through 2002, before I started working at the Lab in 2009.)

I have permission to discuss the case.

I won't name names.

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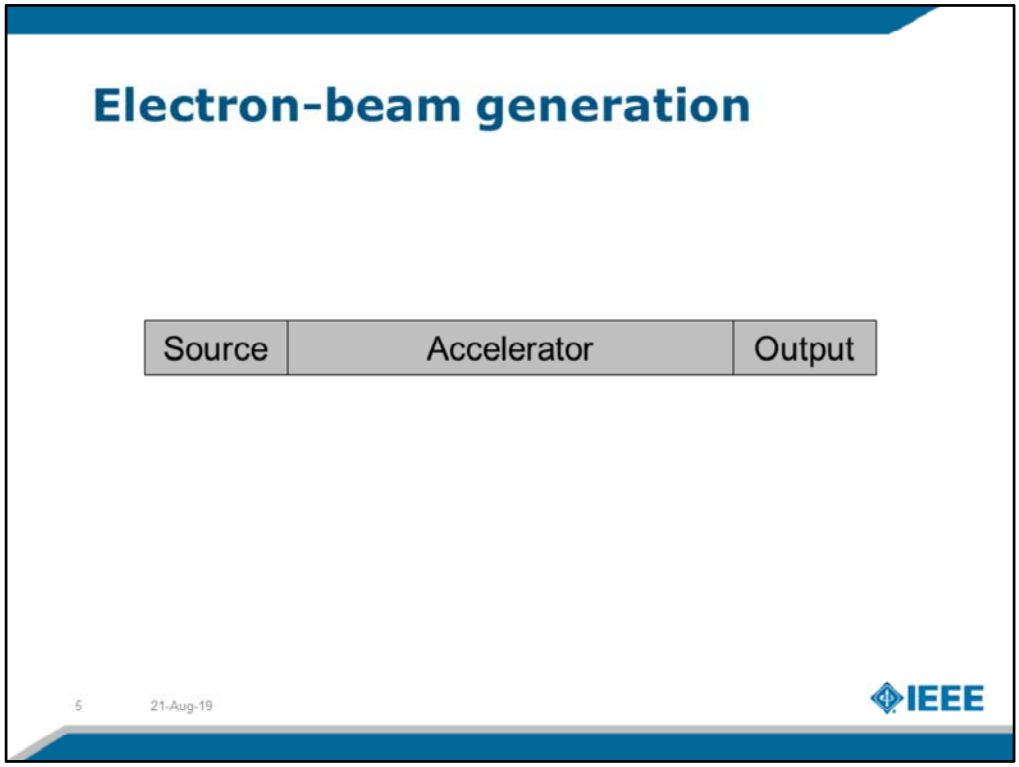
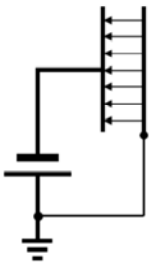
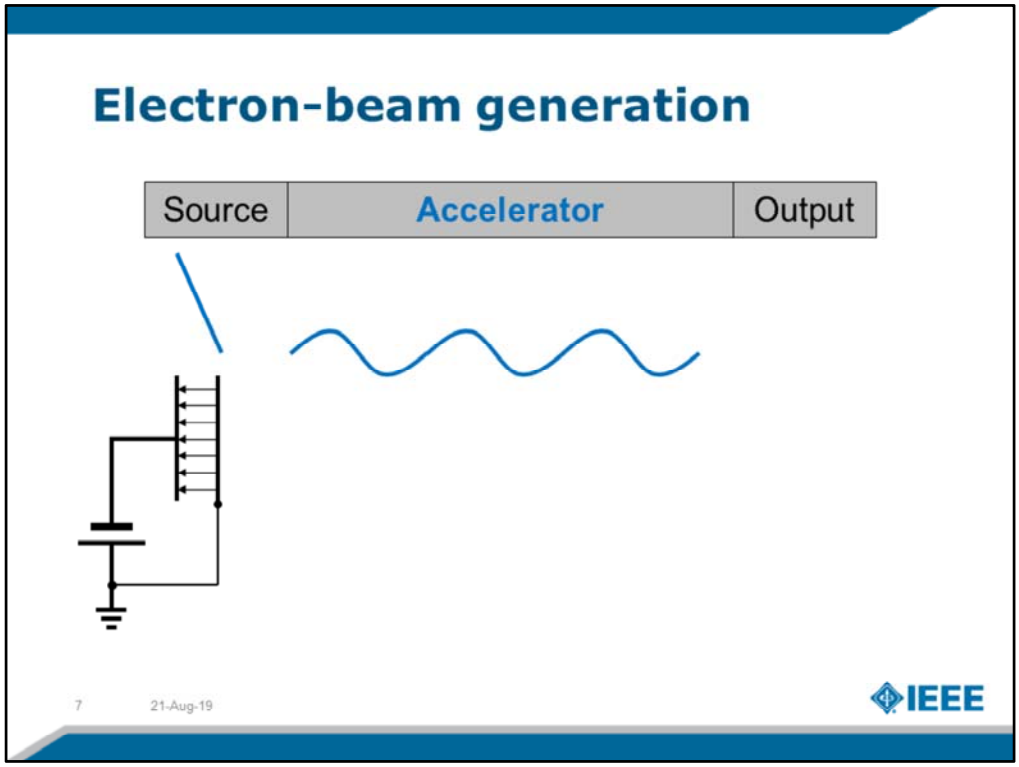


There are three parts to an electron-beam accelerator.

Electron-beam generation

Source	Accelerator	Output





This electrical circuit is oversimplified. There is a third electrode, to draw off electrons from the emitting surface.

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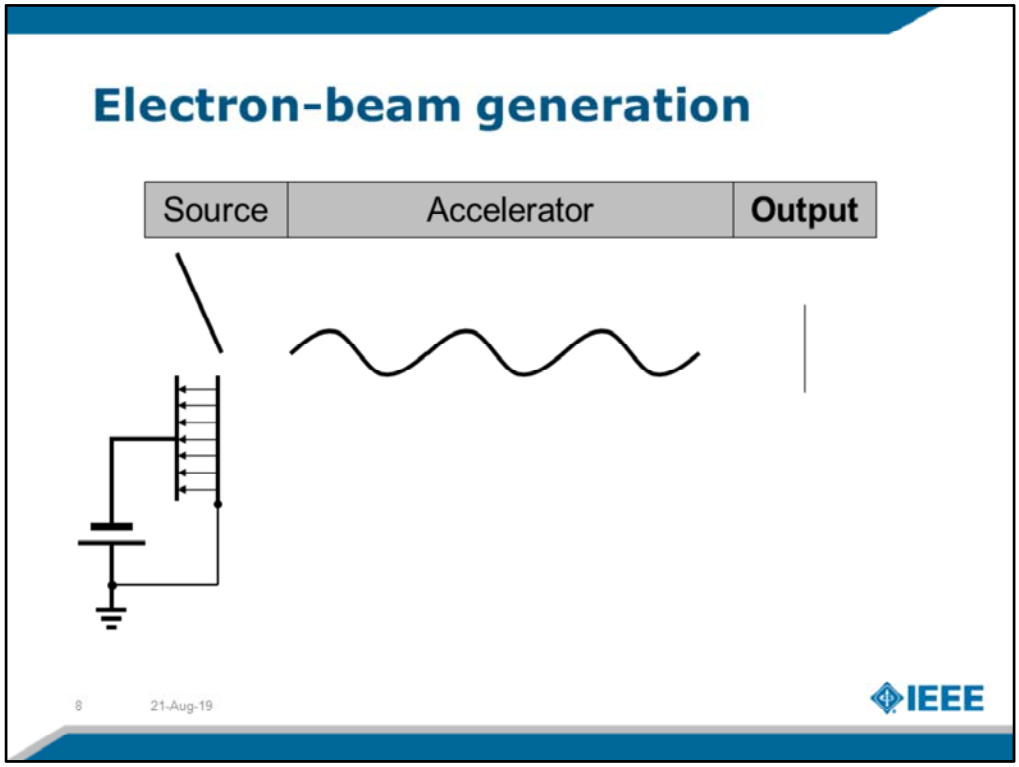

The electrons “surf” on the microwaves. If the electron bunches are phased properly with respect to the microwaves, then energy is transferred from the microwaves to the electrons.

Actually, the microwave source, such as a klystron, works this way in reverse: an electron beam transfers its energy to he microwaves.

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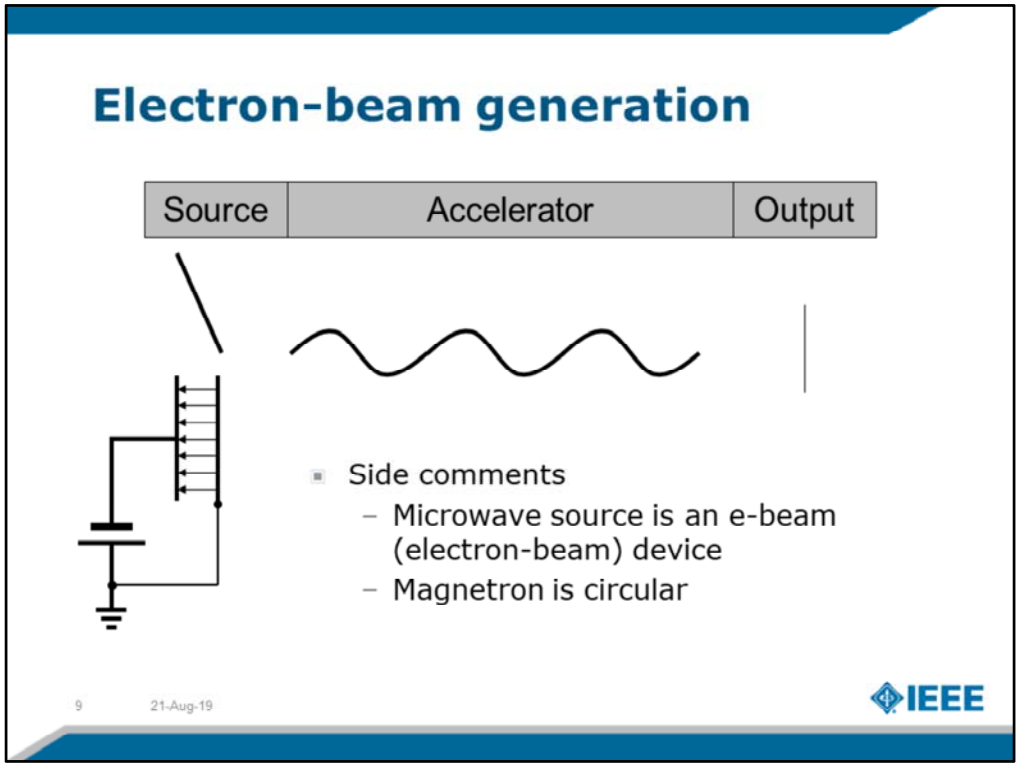
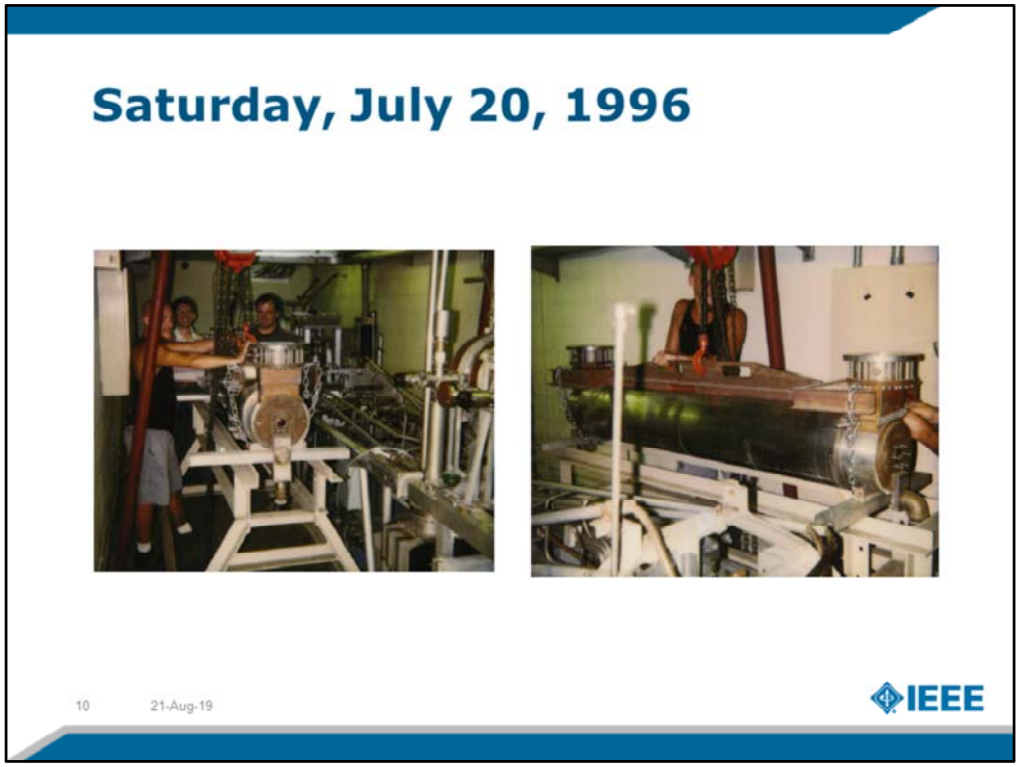


Side comments

Microwave source is an e-beam (electron-beam) device

Magnetron is circular

Philipp Lenard, “Lenard Window” Nobel Prize for Physics in 1905, Hitler supporter, ironically contributed the experimental evidence for which Einstein explained as the photoelectric effect (i.e., energy output independent of light intensity, but greater for shorter wavelengths of light) and won the Nobel Prize for Physics in 1921.



Here I am at NES removing their set of microwave cavities, or “waveguide” as they called it. All that can be seen is the smooth solenoidal magnet around the entire structure.

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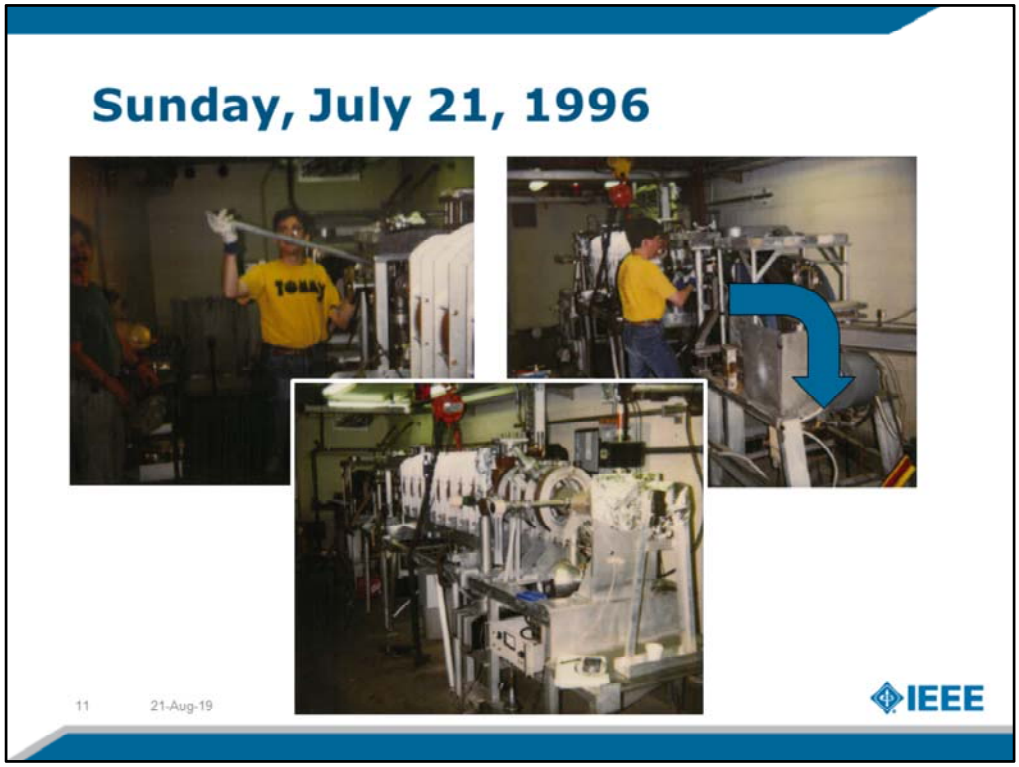
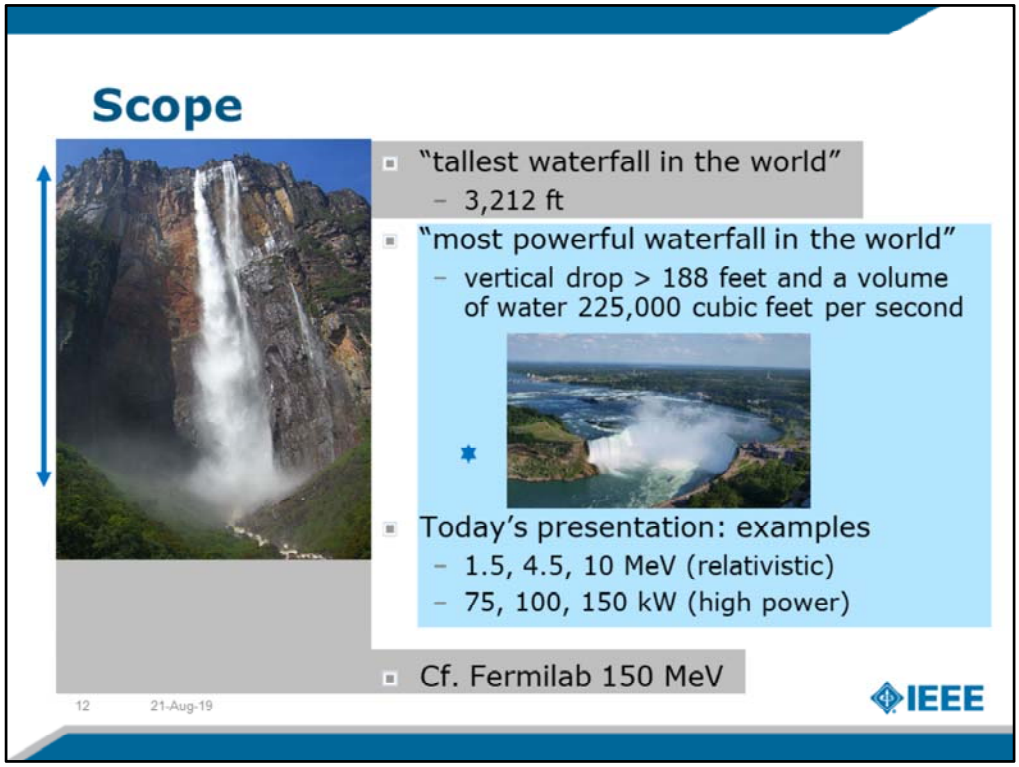


Top right picture is flipped “horizontally” (about its vertical axis) so that the beam deflector going down is to the right instead of to the left.



Picture of Angel Falls is from

https://en.wikipedia.org/wiki/File:Salto_del_Angel-Canaima-Venezuela19.JPG

On Thurs 5/8/2019

Wikipedia states that the attribution is "Diego Delso [CC BY 3.0 (https://creativecommons.org/licenses/by/3.0)]"

.

Niagara Falls is from

https://en.wikipedia.org/wiki/List_of_waterfalls_by_flow_rate#/media/File:Canadian_Horseshoe_Falls_with_Buffalo_in_background.jpg

On Thurs 5/8/2019

From Wikipedia, the description and licensing:

"**English:** Canadian Horseshoe Falls. Clicked from Skylon Tower, Niagara Falls, Canada."

"I, the copyright holder of this work, release this work into the **public domain**. This applies worldwide. In some countries this may not be legally possible; if so: *I grant anyone the right to use this work **for any purpose**, without any conditions, unless such conditions are required by law.*"

https://fnal.gov/pub/science/particle-accelerators/accelerator-complex.html

On Monday, June 3, 2019, indicates that the Femilab FAST is 150 MeV:

"The Fermilab Accelerator Science and Technology (FAST) facility is America's only test bed for cutting-edge particle beams and for accelerator research aimed at intensity frontier proton accelerators. Electrons are accelerated through a 125-meter linear accelerator, called the electron injector, to an energy of 150 million electronvolts…"

The web site doesn't mention the (relatively low) beam power or beam current.

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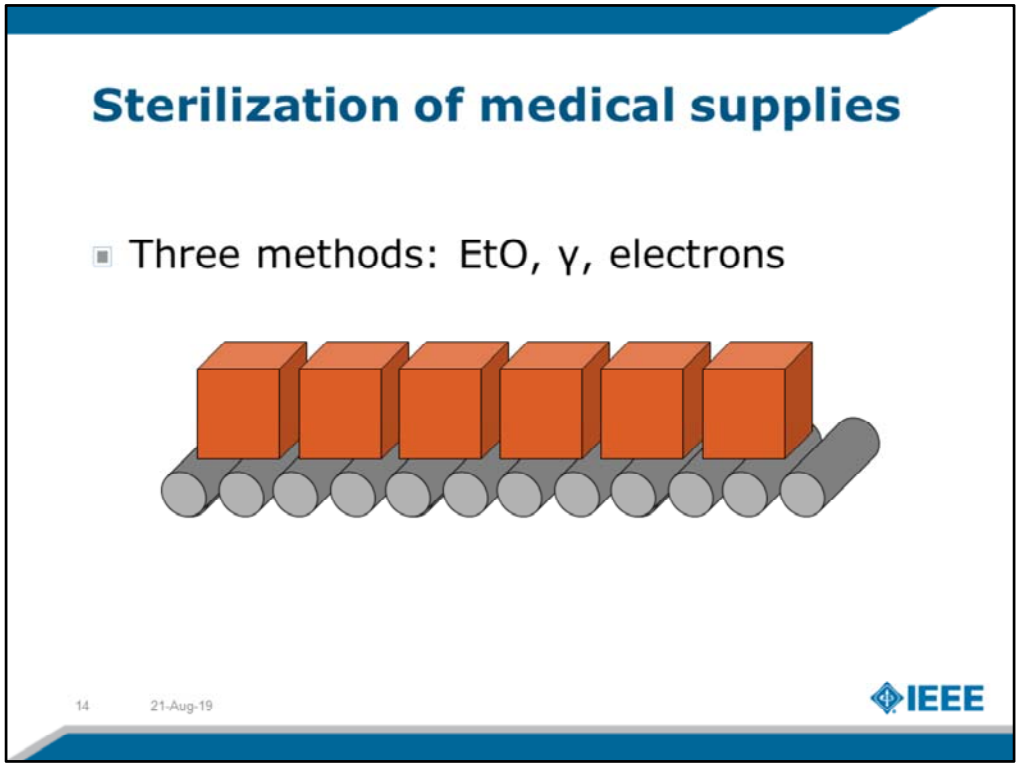
Outline

- Electron-beam background
  - Physics of generation and application
  - Electron-beam applications
    - Sterilization of medical supplies
    - Changing the color of gemstones
    - Sterilizing spices and other foods; water
    - Sterilizing skin for grafts
    - *Removing Teflon from wire*
    - Composite-tape curing during lay-up
  - High-power electron-beam systems

IEEE



The e-beam is scanned back and forth while the boxes of medical supplies pass under that "curtain" of electrons. The conveyor can move at one or two feet per minute. At the end, the boxes may be flipped over for a second pass. The whole process may take only a couple of hours for a truckload.

The alternative sterilization methods are:

EtO (ethylene oxide), which is so dangerous (because it is poisonous and flammable) that I'm told that no new EtO facilities can be licensed, and that existing EtO facilities are grandfathered from the past, and has to go into the product and go out again (Imagine a catheter!)

Gamma-rays from Cobalt-60, which takes several hours of product hanging in totes revolving around for even exposure, and cannot be turned off, and requires replenishment after several years, and requires such tight safeguards that a Co-60 facility is as expensive as an e-beam facility, especially now that Co-60 is no longer being subsidized.

Heat is a possible sterilization method, but e-beam is non-thermal, so is appropriate for many plastics and liquids.

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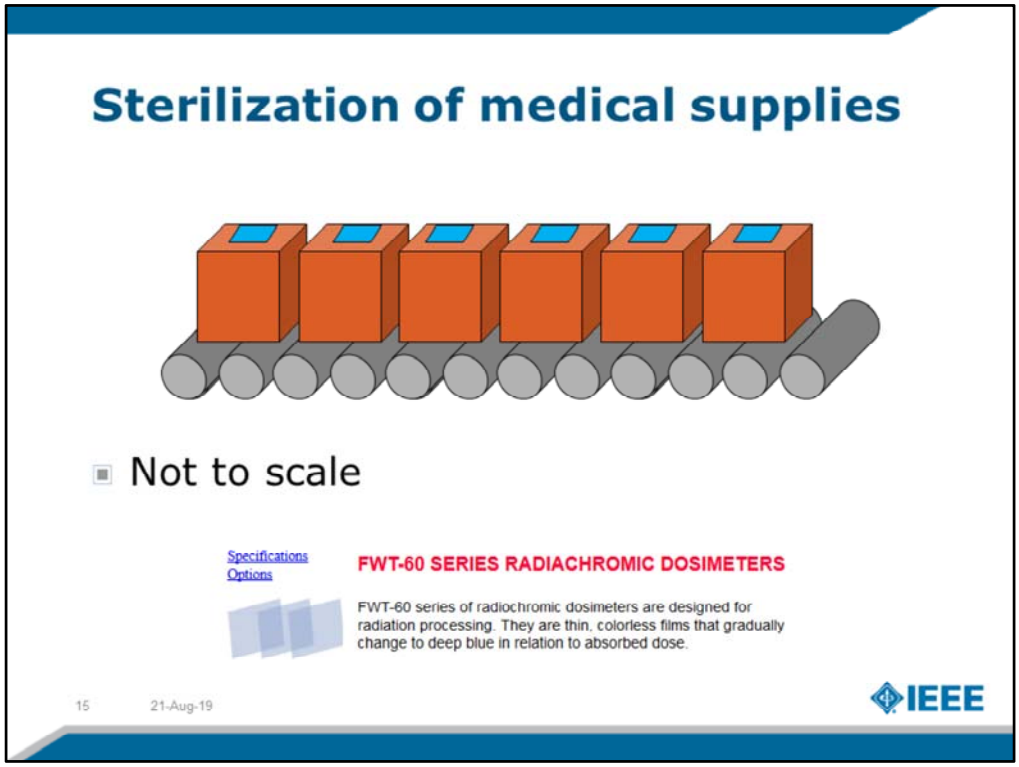

Each of the little blue squares is “radiachromic film” from Far West Technologies in Goleta, CA. They start off clear and turn darker blue the more they are irradiated. They are accurate to 1% at best, for one standard deviation, which I know because I had the opportunity to sift through so much data that I had a statistically significant (dozens or hundreds, as I recall) “triplets” (i.e., three small blue squares in one foil packet) that averaged to a specific quantity. E.g., if 5 Mrad were the nominal dose for our Baxter medical product, I could find many, many packets that read out as 5.0 Mrad or 4.9 Mrad or 5.1 Mrad. I took one such group, i.e., just the 4.9 Mrad, for example, and then looked at the individual blue squares. In an ideal world, they would all read the same and the standard deviation would be zero. In practice, even just one standard deviation was at least 1% in all groups.

Picture that is a screenshot is from

http://www.fwt.com/racm/fwt60ds.htm

On Fri, May 10, 2019

Also, I found a large discrepancy with Extremely Low-Dose Radiation. I did a simple experiment where I put RC (radiachromic film) A and RC B onto the accelerator, not in the direct beam path. When it reached a reasonable shade of blue, after a couple of days or a week, I removed A and put in C. I left C there for about the same amount of time and then removed B and C. The readings A + C were nowhere near that of B.

.

Examples of e-beam facilities

- Five or six at the right
- Four shown below
- Maquiladora, NAFTA 1994

16

IEEE

Both pictures were taken from Google Maps, one from satellite view and one from street view, on Fri 1/25/2019, at 6pm, djw.

Note four truck bays (loading docks) in the street view picture, and about five or six truck bays in the satellite view picture.

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A “maquiladora” is a special tax zone so that parts can be assembled in Mexico, and then brought across the border for sterilization, all without paying excessive tariffs. Sterilization is considered to be the last step in the manufacture of medical supplies.

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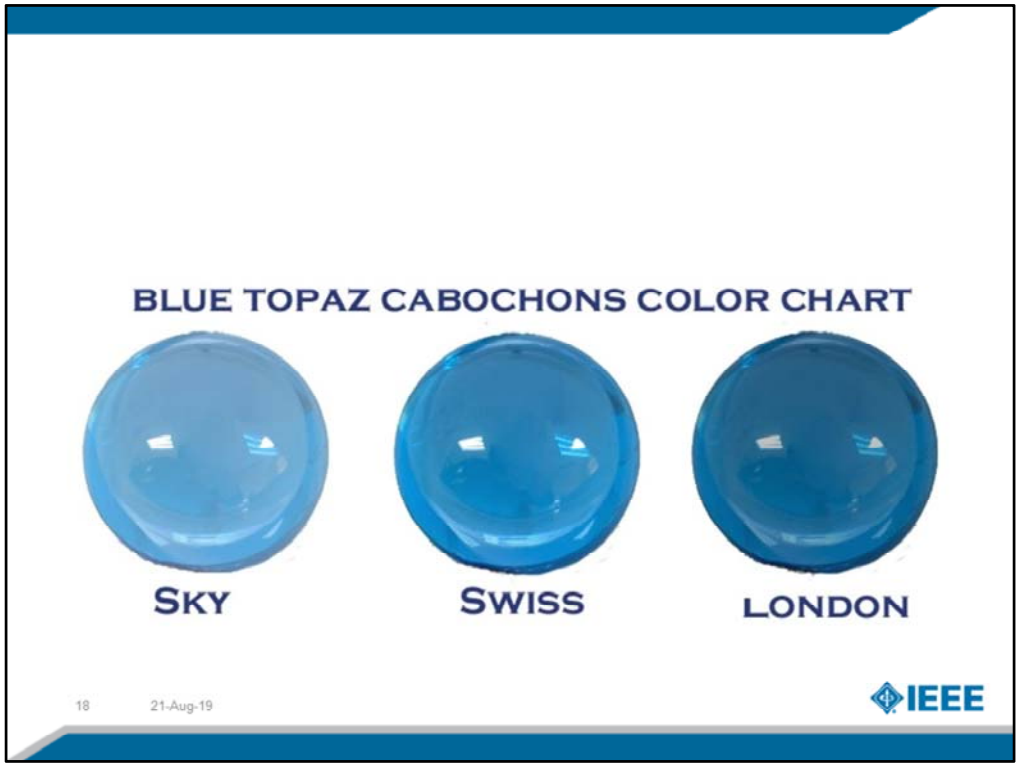
Image of topas is from a file named
topas-london-blue_from www.meelis-bluetopaz.com.jpg
Downloaded on April 1, 2016



This image was downloaded on April 1, 2016, and is from a file named topaz-cabochons-color-chart_from www.wholesale-cabochons.com
Or
blue-topaz-color-chart_0_from www.wholesale-cabochons.com
.

Picture of safe is from

https://www.nationwidesafes.com/11325.html

On Thurs 5/8/2019

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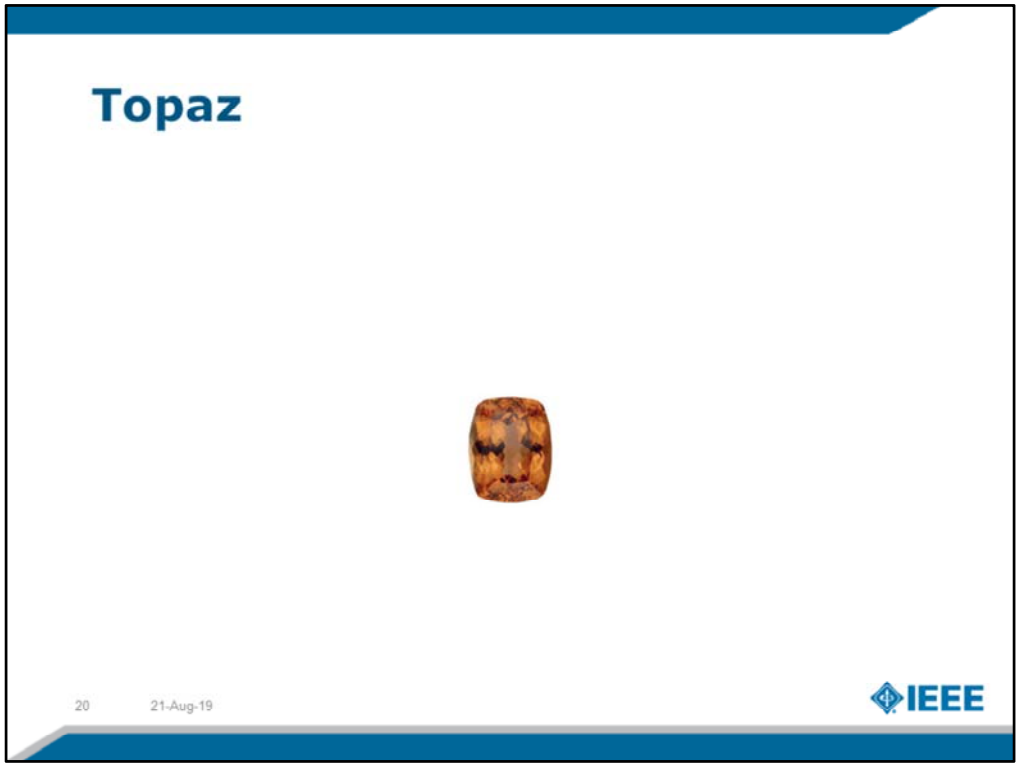
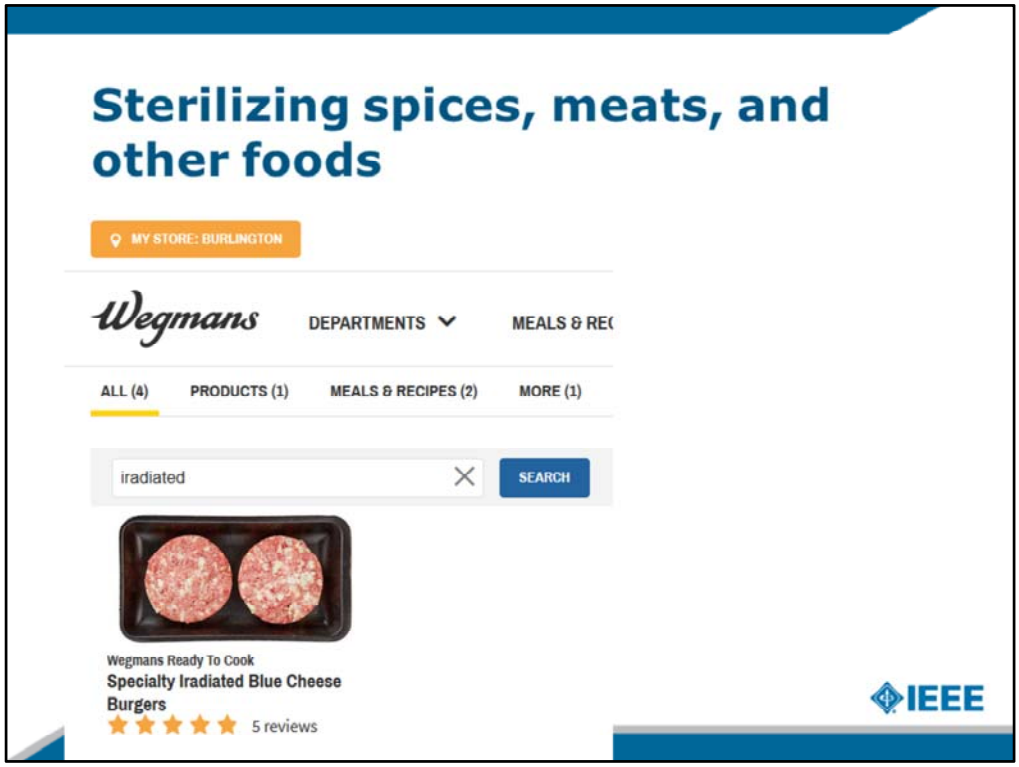


This file was downloaded on April 1, 2016 and is from a file named precious-imperial-topaz-24.09-t_from www.minerals.net

This image was downloaded on April 1, 2016 and is from a file named 19fkygzsjtgvyjpg_from jezebel.com



The picture is downloaded from

https://www.wegmans.com/products/meat/ready-to-cook/burgers/specialty-iradiated-blue-cheese-burgers.html

On Fri, May 10, 2019.

All 5 reviews comment on the great blue-cheese taste, but none on the irradiation.

.

J: An internet search indicates that irradiated meat can be kosher. Note, however, that blue-cheese burgers are not.

J: Also, note that I know how to spell “irradiated”

.

Sterilizing red meat approved by the US FDA in December 1997

Irradiating Red Meat Approved As Means to Kill Deadly Germs

Process Safe and Won't Alter Food, F.D.A. Says

By GINA KOLATA

The Food and Drug Administration yesterday approved the irradiation of red meat, a measure that food safety experts said could nearly eliminate dangerous bacteria that cause food poisoning from the meat supply if consumers accept it.

Dr. Michael Friedman, the Acting Commissioner of Food and Drugs, said the agency was satisfied that irradiation was safe, that it did not demonstrably alter the nutritional content of food, that it did not change the flavor or aroma of meat, and that it killed nearly all bacteria on meat that can sicken and kill.

Companies would bombard hamburger or sausages, for example, at the end stages of processing with radiation that kills bacteria by fracturing their genetic material. But it does not make the meat radioactive.

Dr. Jim Dixon, a food microbiologi-

demand for it. Although it is often stated that consumers are terrified of anything with the word radiation in it, evidence is mixed on consumer reaction. But it is true that there is simply no organized movement demanding irradiated food.

Because the Agriculture Department must also issue regulations governing the process of irradiating red meats and the labeling, it is unlikely that irradiated meats could be available before next summer, said Jacque Knight, a spokeswoman for the department.

Yet, when it finally happens, the irradiation of meats like ground beef, experts say, could completely destroy bacteria like E. coli 0157:H7, a strain that infested hamburger meat processed by Hudson Foods last summer, making 17 people ill and forcing the plant, in Columbus, Neb.,

This is a scan of my hardcopy original (NY Times) newspaper clipping that I found while cleaning out my files.

Djw

5/2019

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Sterilizing red meat approved by the US FDA in December 1997

THE NEW YORK TIMES **NATIONAL** W.

F.D.A. Approves Irradiation of Red Meat

Continued From Page A1

tory for consumers and the red meat industry." Moreover, said Patrick Boyle, the president and chief executive officer of the institute, companies expect to use it.

"I know for a fact that there is sincere interest on the part of the meat industry processors, retailers, and food service operators," he said. He added that "a number of companies," anticipating the F.D.A.'s decision, have begun conducting tests of irradiation to prepare to irradiate on a large scale.

Red meat irradiation, predicted Dr. Michael T. Osterholm, an epidemiologist at the Minnesota Department of Public Health in Minneapolis, will not repeat the slow path of poultry irradiation. Instead, he said, it will pull poultry irradiation along with it as consumers start to demand that their meat be cleansed of bacteria. And so, he said, the introduction

A watershed event or a shortcut for the meat industry?

the safety of irradiated food but was worried that meat processors might come to rely on irradiation to sterilize food that they processed under filthy conditions.

"Our feeling is that the industry should clean up its product as much as possible," Dr. Jacobson said. "If that fails to provide safe food, then they certainly should provide irradiation. But irradiation should be a last resort."

Ms. Knight of the Agriculture Department said that the agency will move as quickly as possible to issue rules so irradiation of red meats can proceed.

Until now, said Dr. Dean Cliver, a

had shown that irradiation of meat was safe and effective in killing most bacteria. In fact, Mr. Dietz said, when Isomedix submitted its petition, "the F.D.A. was quite optimistic that they could have it completed in a relatively short time."

Food irradiation was endorsed more than 20 years ago by the World Health Organization and the International Atomic Energy Agency. It has been advocated by the American Medical Association, the American Dietetic Association, and by an expert committee appointed by the American Gastroenterological Association, among others.

"Realistically, all safety concerns have been answered," said Dr. Sherwood Gorbach, a professor of community health and medicine at Tufts University School of Medicine in Boston who was a member of the gastroenterological association's committee.

In the meantime, food poisoning

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radiation to
Here is how
sold by MDS

Food Is Mo
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Food is place
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through a ro
prevent the r
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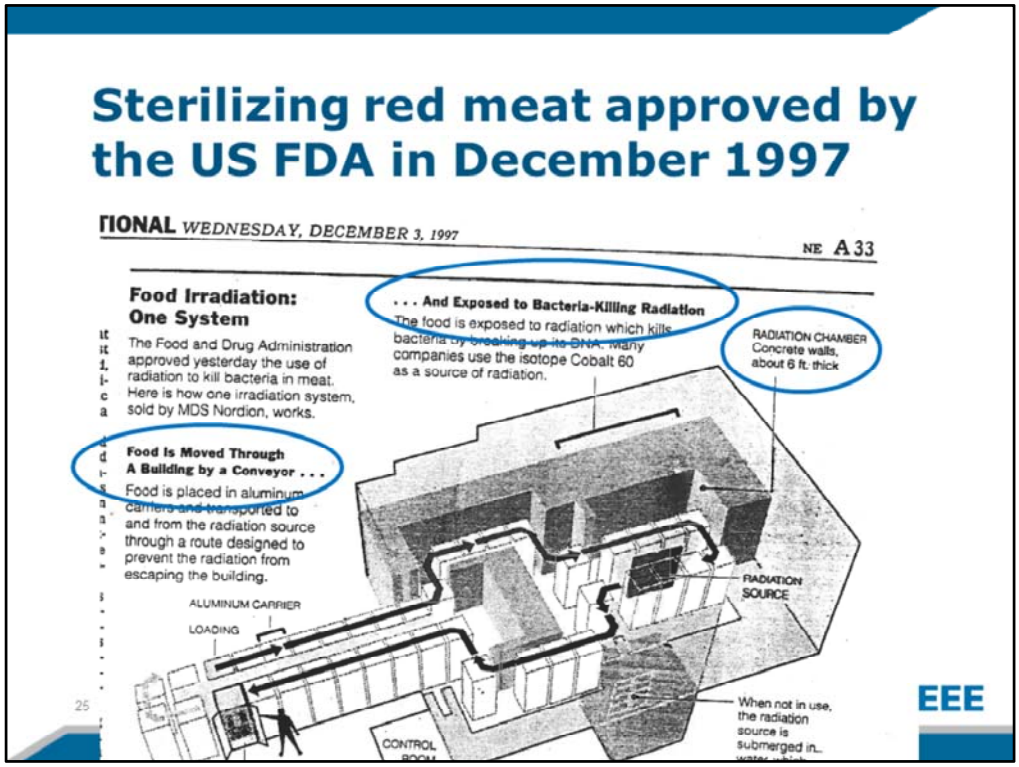
ALL

LOA

Sterilizing red meat approved by the US FDA in December 1997



This is like the system that I'm going to describe.

.

Decontaminating ground water

Application of Induction Accelerators for Electron-Beam Radiolysis of Contaminated Water

NSF Phase II Status Report

May 5, 1998

Science Research Laboratory, Inc.
Daniel J. Weidman, Ph.D.
James Moran, Ph.D.

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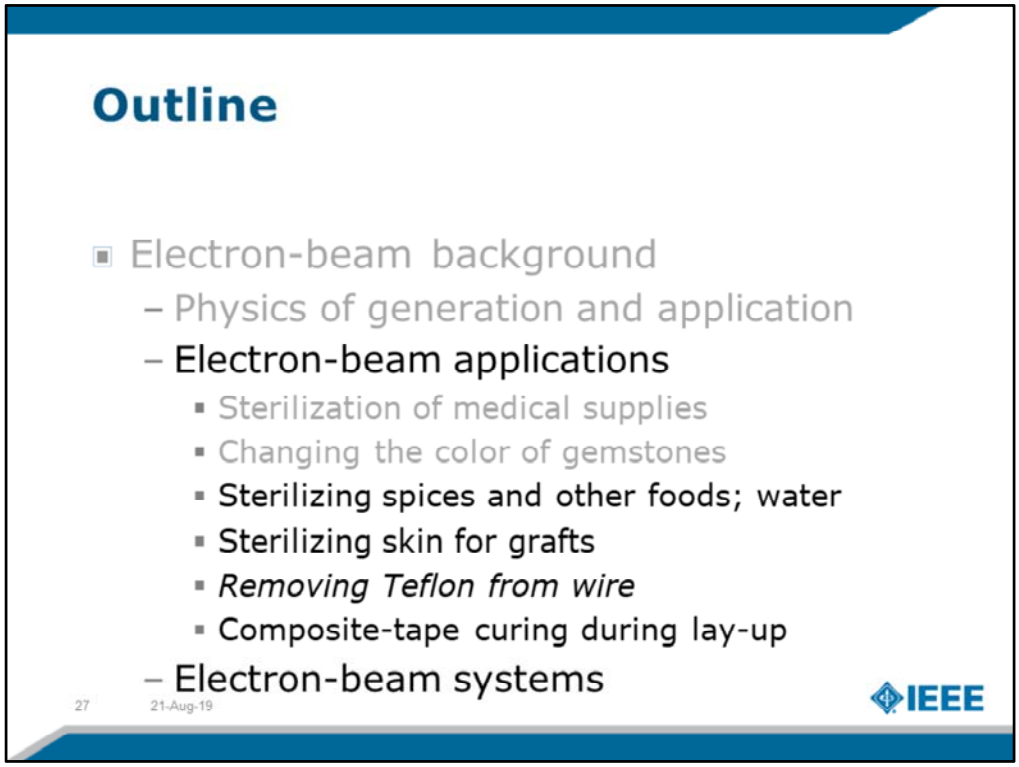

Composite-tape curing during lay-up: this is a bit of a diversion, because it is lower energy and lower power.

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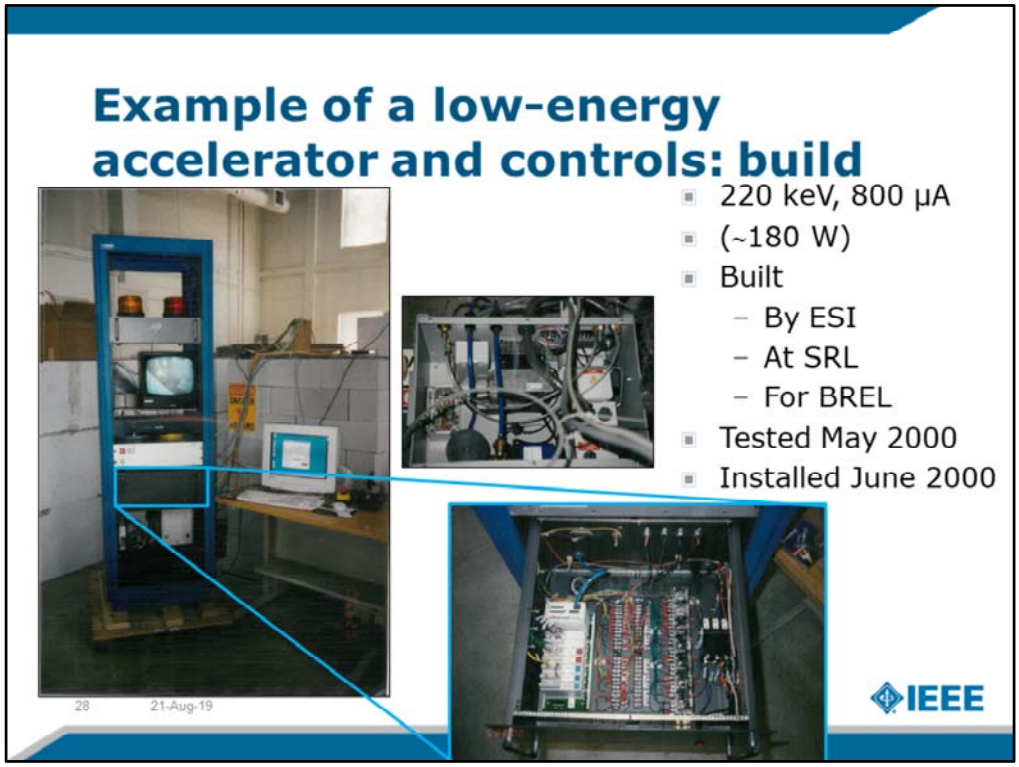

ESI is Electron Solutions, Inc..

SRL is Science Research Laboratory.

BREL is Boeing Radiation Effects Laboratory, Seattle, WA.

At the bottom right is the interface box, which Dan W. wired, for the Boeing/ESI EB-ATP, 5/29/2000

As an interesting side-note, a lower-paid technician (who was very good) and a higher-paid engineer (me) each wired one of these boxes. I was careful and slower, and the unit worked almost as soon as I finished, with only some minor debugging. The unit assembled by the technician was made to the wrong revision, and required so much debugging that the cost of the labor for the boxes was about the same as each other. If there were larger quantities than just two, the technician would have likely been more cost effective than I was.

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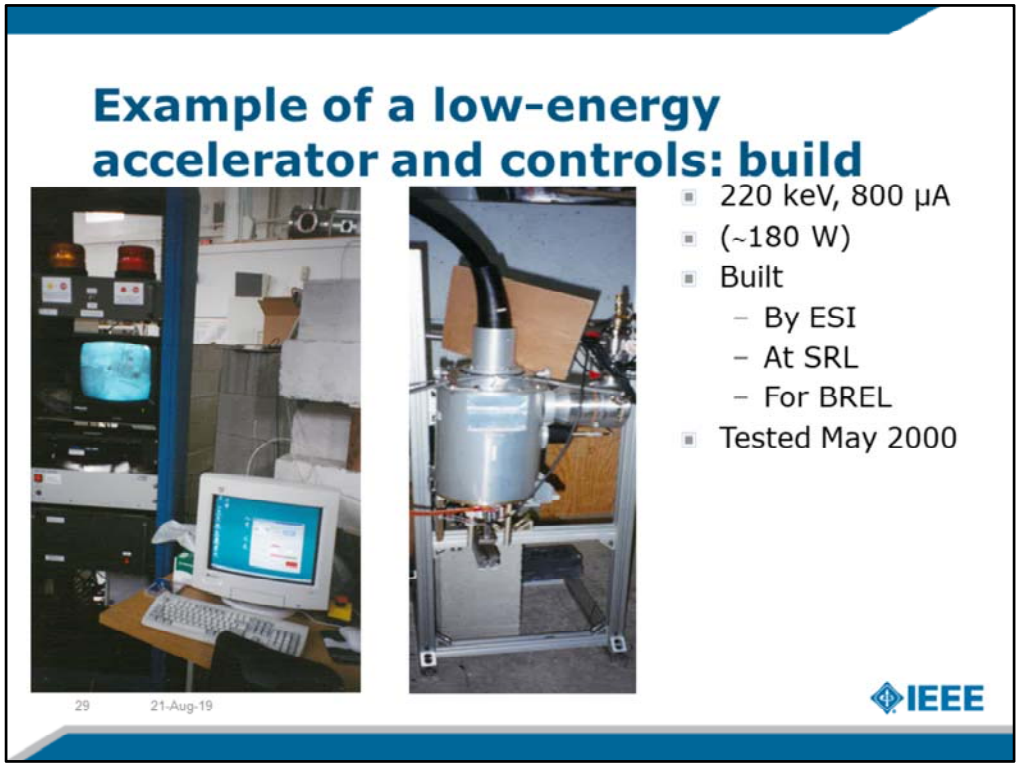

ESI is Electron Solutions, Inc..

SRL is Science Research Laboratory.

BREL is Boeing Radiation Effects Laboratory, Seattle, WA.

On the left are the controls for the EB-ATP for Boeing from ESI.

On the right is the e-gun for the EB-ATP for Boeing from ESI.

Both pictures: Tuesday, June 27, 2000.

.

Example of a low-energy accelerator and controls: build

- 220 keV, 800 μA
- (~180 W)
- Built
  - By ESI
  - At SRL
  - For BREL
- Tested May 2000

30 21-Aug-19 IEEE

ESI is Electron Solutions, Inc..

SRL is Science Research Laboratory.

BREL is Boeing Radiation Effects Laboratory, Seattle, WA.

“Vacuum box” and HV power supply for the EB-ATP for Boeing from ESI, Tuesday, June 27, 2000.

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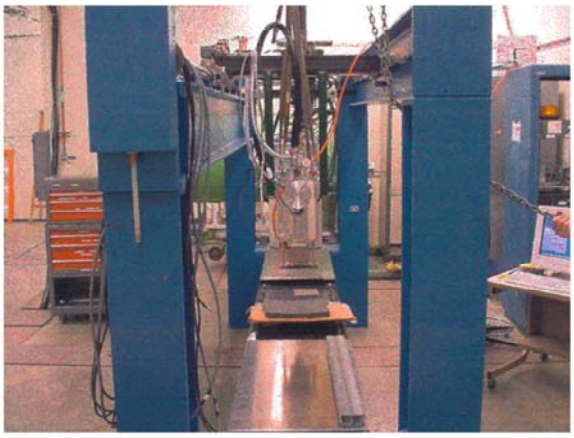
Example of a low-energy accelerator and controls: install



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IEEE

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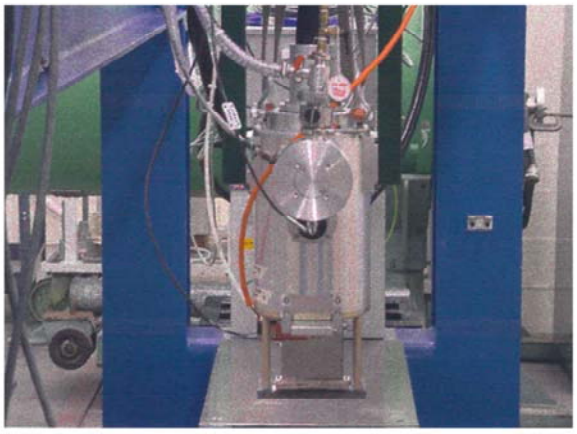

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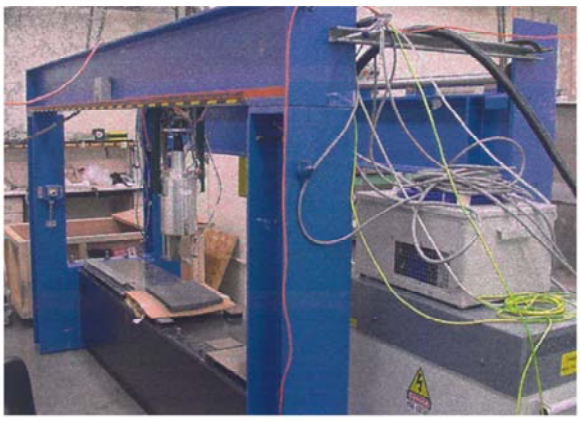

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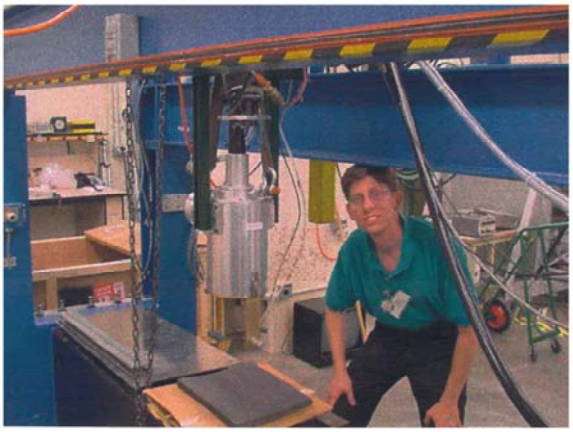

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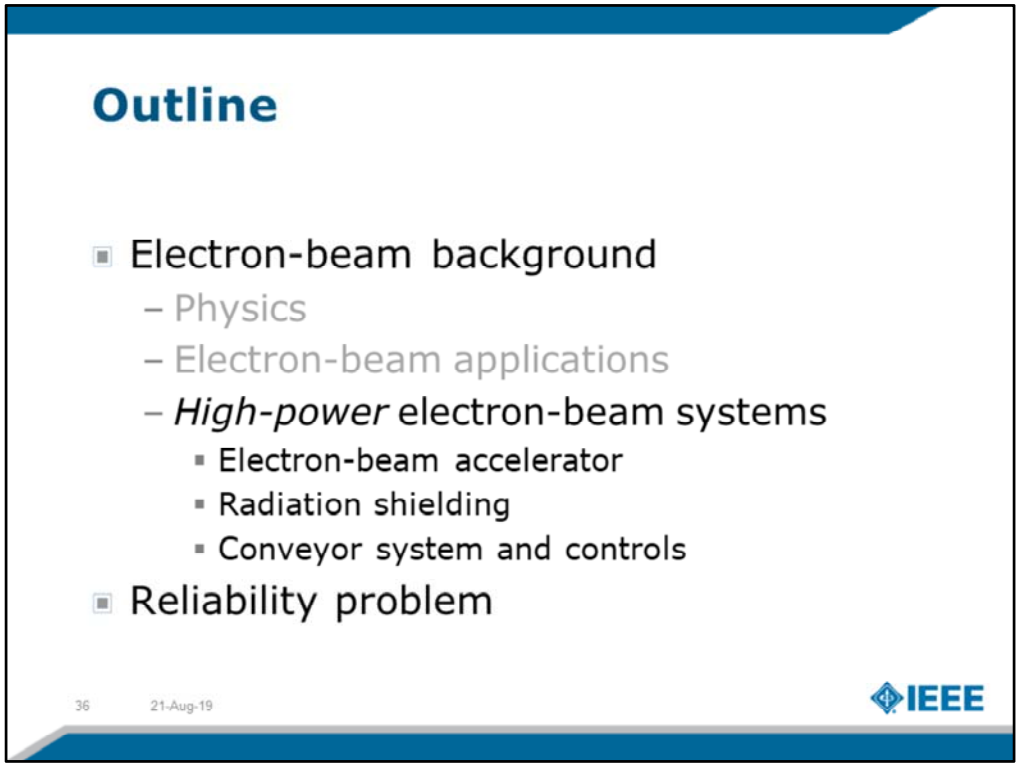

Electron-beam systems are tailored to their application. What follows is consistent with most of the applications that I've described.

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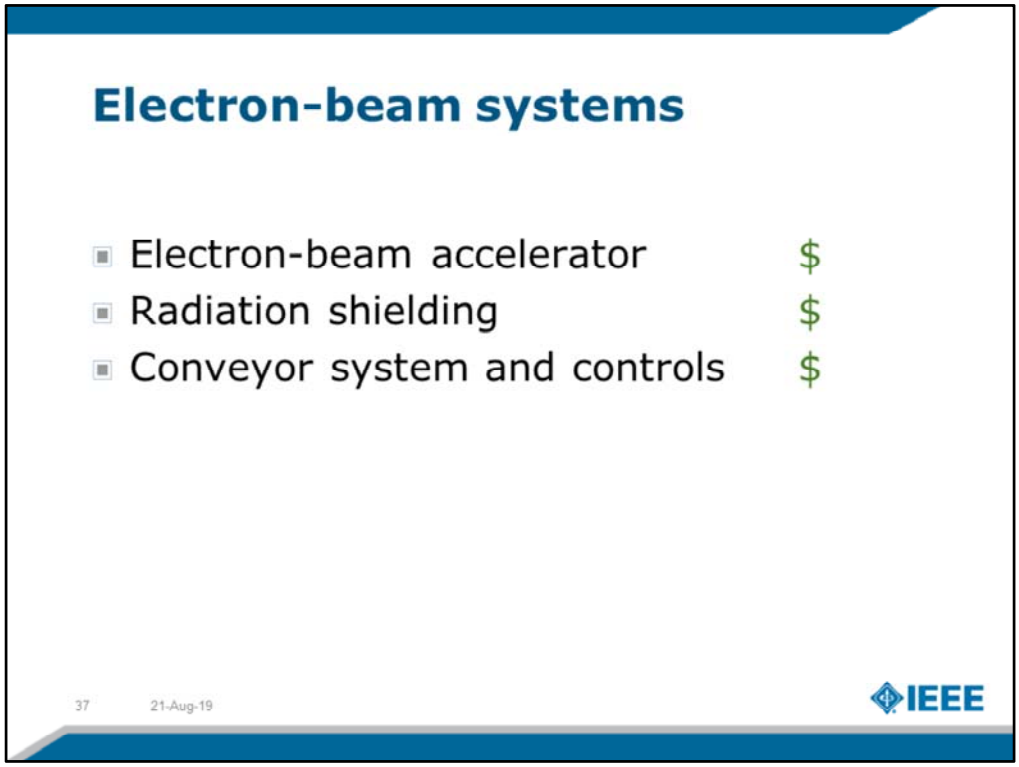

There are three portions to an electron-beam system, and they cost about the same as each other. At the time, they each cost about one million dollars.

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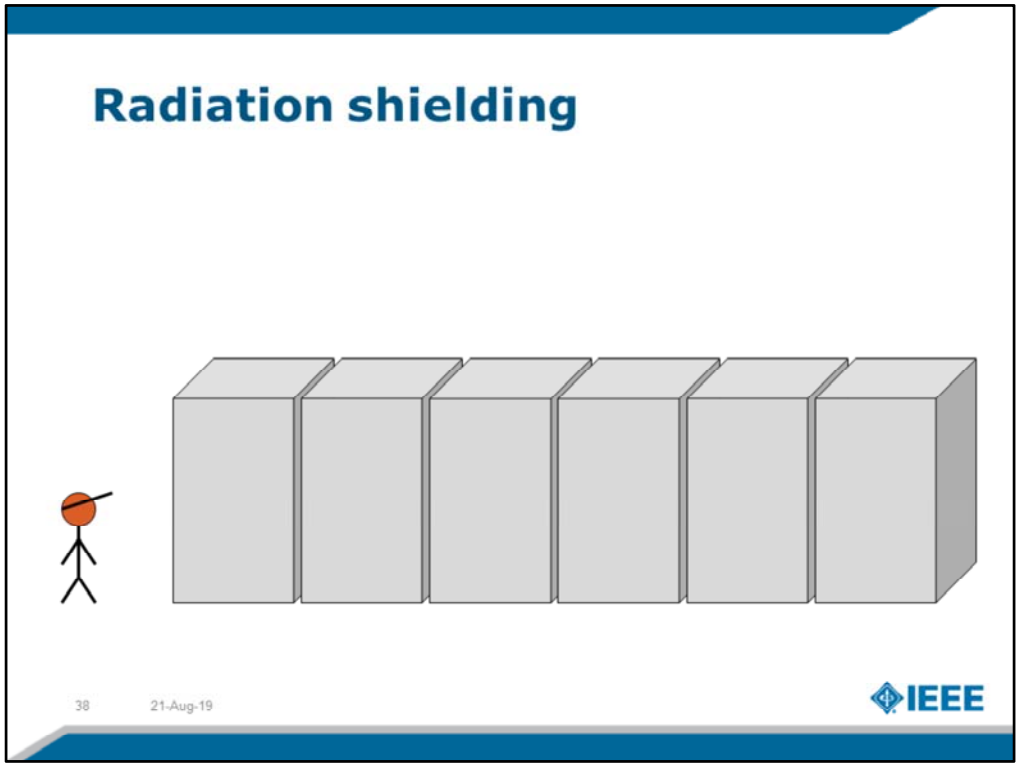

Shielding is roughly linearly proportional to electron energy, with some dependence on electron-beam current, with which the radiation levels outside the shielding are linear.

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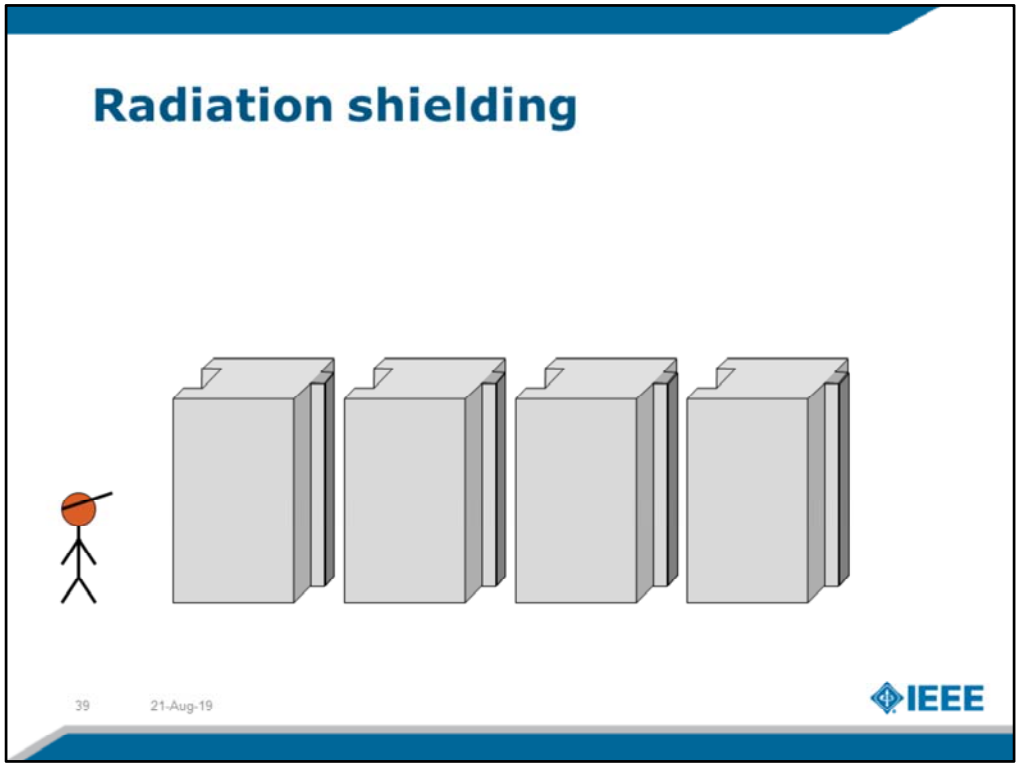

In practice, the shielding has a geometry to prevent a straight path that bypasses the shielding.

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Radiation shielding alternatives

- Lead sheet or lead plate
  - Thin and soft: requires support
    - Time (labor/cost) to design support structure
    - Floor space required for support
    - Therefore, no advantage over cement or concrete
- Diesel fuel
- Sand-filled boxes for mass

40 21-Aug-19 IEEE

Tues 2/19/2019, djw: Picture of coffin grabbed this afternoon from Grainger:

https://www.grainger.com/product/6CAU3

$413.03 each, including body bag

That's like what I saw at Beta Development in or near Pleasanton, CA in the late 1980's.

Tues 2/19/2019, djw: Adrian S. explained to me that diesel fuel, which is available for the backup generator, is used to shield the reactor on a nuclear submarine. As diesel fuel is used, seawater is pumped in to maintain the level of the diesel fuel, which floats on the water.

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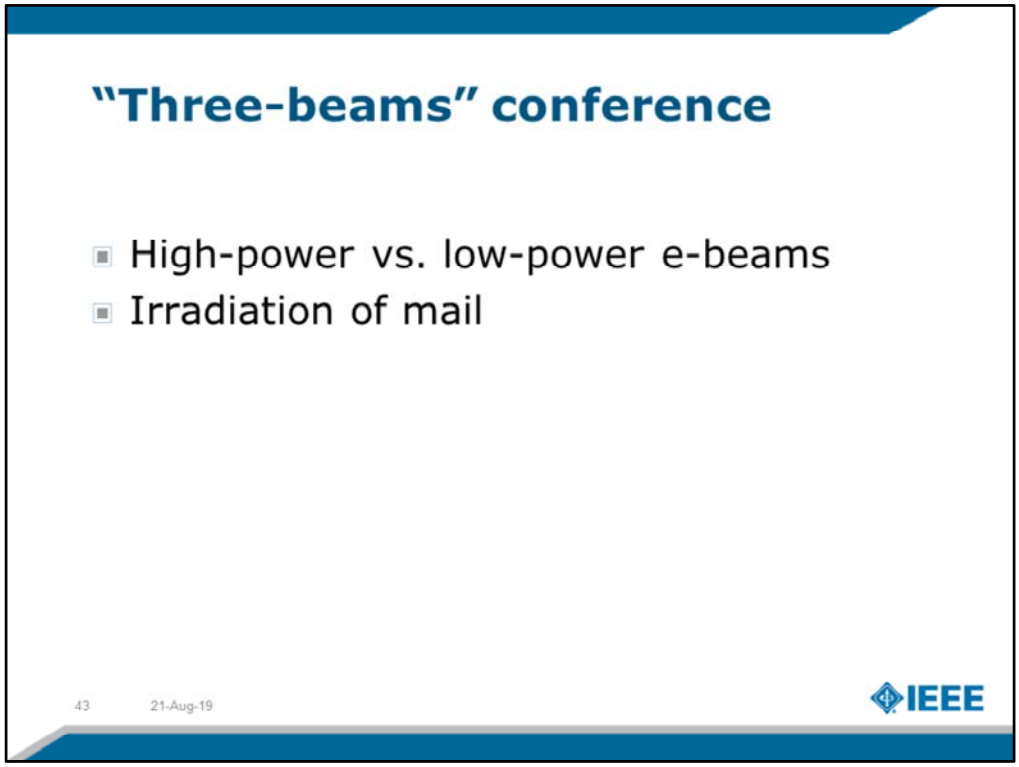
Outline

- Electron-beam background
  - Physics
  - Electron-beam applications
  - Electron-beam systems
    - Electron-beam accelerator
    - Radiation shielding
    - Conveyor system and controls
- Reliability problem

Outline

- Electron-beam background
- Reliability problem
  - Initial meetings
  - Written testimony
  - Deposition
  - Trial



The EIPBN is the Electron, Ion, and Photon Beams Conference, and Nanotechnology. These electron beams are lower power than those in this presentation, and much lower energy than at a research accelerator such as CERN. Out of several hundred, or more, people attending, there were at least three people with high-power electron beam experience:

Me,

One salesman for high-power electron beams was at a vendor table.

There was a speaker about irradiation of mail for congressman. After his presentation, I went up to him and we spoke. When he asked if I were interested, I mentioned two other colleagues, one who designed the systems that I helped build and install, and one who designs and builds systems in a shop in Connecticut.

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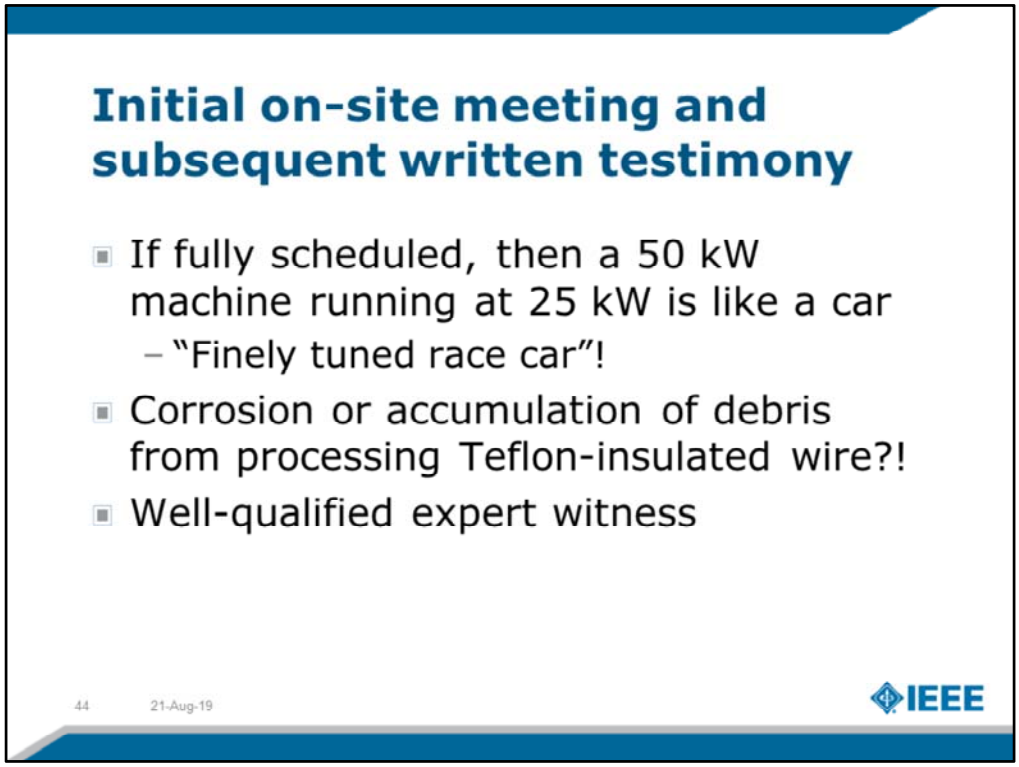

The e-beam system in question was 50 kW and was running at 10 to 20 kW. I explained that this is analogous to a delivery truck running at 10 or 20 mph rather than 50 mph. Even a service contract omits that a delivery truck between Boston and New York has to operate at highway speeds, that requirement is implied by common sense. That was never countered.

The response was that an e-beam accelerator is like a finely tuned racecar. Poor operation was blamed on corrosion. Corrosion was blamed on processing Teflon. I had no experience with Teflon, but had observed such corrosion, thereby using my lack of experience with Teflon but experience with corrosion as the basis of pointing out that the Teflon is not causing the corrosion. In fact, I think that the corrosion is caused by the formation of ozone by electron-beam ionization of the air. Ozone is so corrosive that it is used to sterilize water in swimming pools so that less chlorine can be used.

I pointed out that the other expert witness seemed very well qualified for electron beams in vacuum, but not propagating in air, which was the point of this case.

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  - Deposition
  - Trial

Full-day deposition

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L.A.Law

Image of conference room table is from
http://www.rofinc.net/wp-content/uploads/large-conference-table-300x279.jpg
On 12/14/2017

Image of buildings is from
https://www.favrify.com/wp-content/uploads/2015/01/851-990x575.jpg
On 12/14/2017

Deposition with many people

- Expert witness
- Company A
  - Lawyer
  - Technical Representative
- Company B
  - Lawyer
  - Technical Representative
- Company C
  - Lawyer
  - Technical Representative
- Videographer
- Stenographer
- Summer interns

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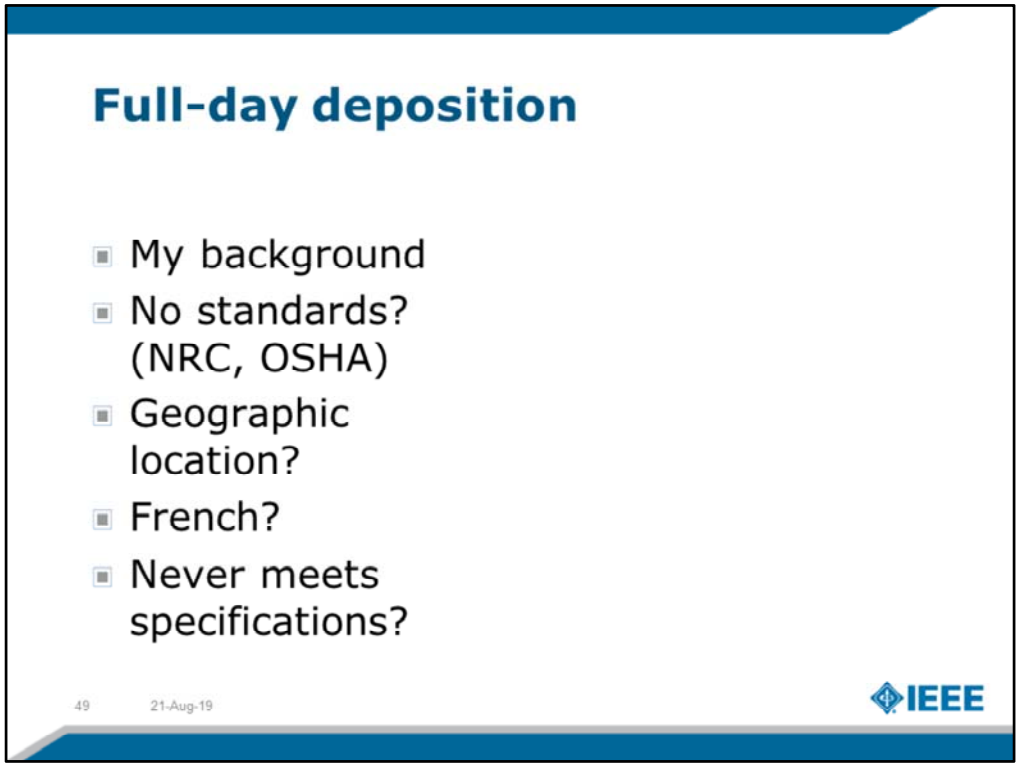

I was asked my background, like in the movie, “My Cousin Vinny.” This was established carefully, step by step, going back in time, listing my experience with each electron-beam machine, rather than simply asking me to describe my experience. The stenographer seemed impressed.

This accelerator was state-of-the-art, so there are no standards that would apply, right? ….I was asked. I responded… NRC, OSHA.

I was asked about the distance between a couple of cities, and had no idea, and then was asked if they were a one-day drive apart. This may relate to the possibility of trucking product from one facility to another.

I was asked about my proficiency in French. This may have been related to the microwave device, a klystron, built by Thales. The specifications sheet was in English and in French.

I was told that an e-beam accelerator customer can’t expect a vendor to meet the design goals, right? I disagreed.

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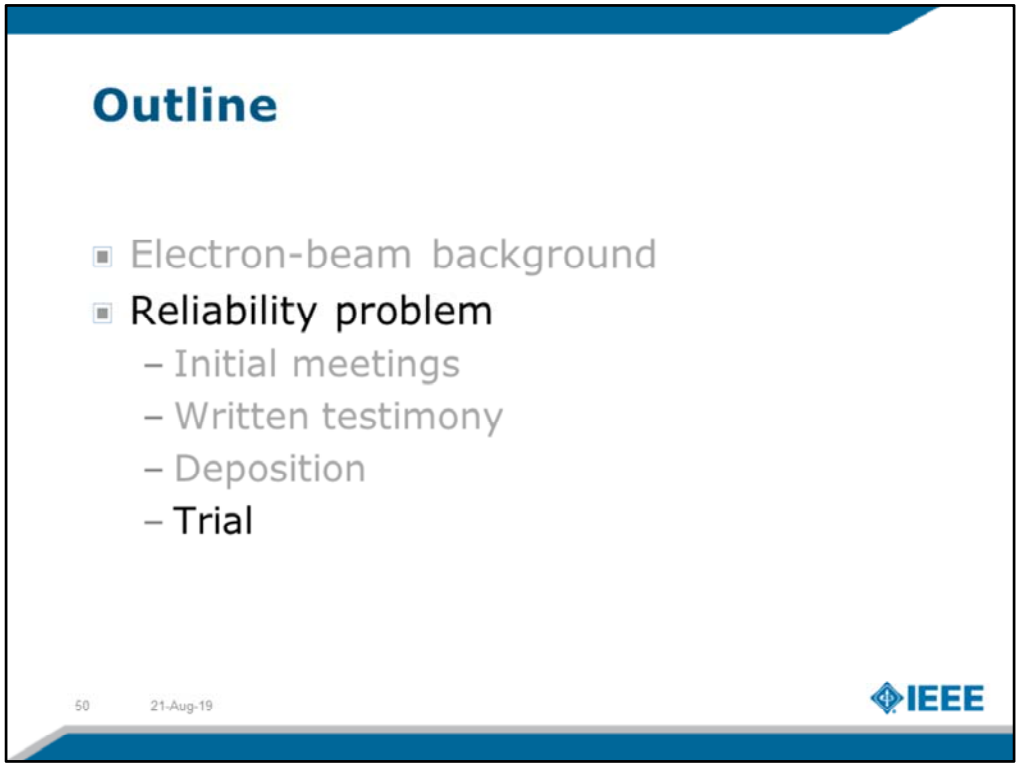

The trial date was set aggressively early by the judge, according to the lawyer with whom I worked. Therefore, while all the lawyers were working as fast as possible, the trial date came. The President of the e-beam facility testified all day. From my written testimony and my deposition, it was known pretty well how things would go if I testified. The next morning, the case was settled. If it hadn't been settled that day, then I probably would have testified. Then we went out to a nice Italian restaurant.

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Picture of big head of Themis blindfolded is "Justice" and is from

https://en.wikipedia.org/wiki/Justice_(sculpture)#/media/File:NewarkJustice1.jpg

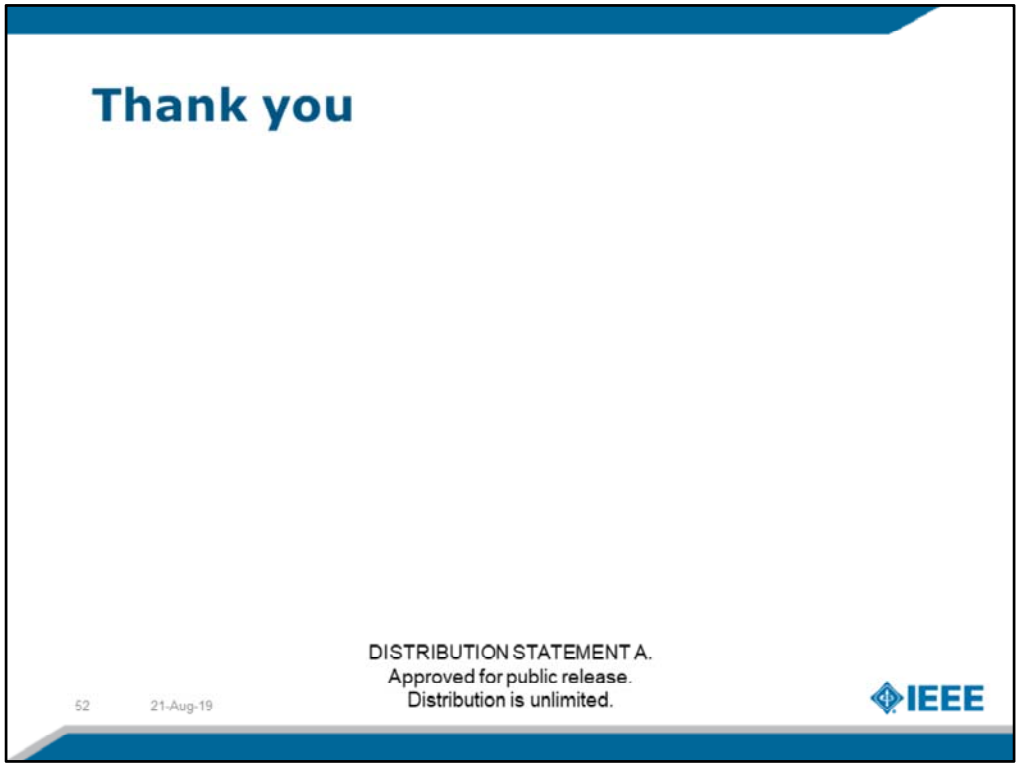
On Thurs 5/8/2019

Wikipedia states that the "author" of the photograph is: "By Carptrash at the English language Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=24612393"

Wikipedia also states the following:

"Justice is a 1991 statue by Diana K. Moore.[1] The statue, the large blindfolded head of the Greek titaness Themis, is currently located in the courtyard in front of the Martin Luther King, Jr. Federal Courthouse at the Government Center in Newark, New Jersey."

Wikipedia states that the statue is 11 feet tall: "*Justice* is 11 ft (3.4 m) tall, 8.8 ft (2.7 m) wide, 9 ft (2.7 m) long, and made of cast concrete. "



Afterwards, I was kept on as a consultant, and shopped around for a new electron-beam system, gathering quotations anonymously.

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Daniel J. Weidman

- SB, Physics, MIT
- MS and Ph.D., EE, University of Maryland
- Author or co-author of more than
  - 20 journal articles & technical reports in publications
  - 60 conference presentations
- Co-inventor, Bulk Plasma Generation (US patent 5,051,659)
- Senior Research Scientist, Science Research Lab
- Reliability Engineer in the semiconductor industry, TEL NEXX
- MIT LL Mission Assurance Engineer 2009 to present
- 2012-2014 IEEE Boston Reliability Chapter Chair

IEEE ReliabilitySociety

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J: I went to school and I did various things… but enough about me.

(I added this slide to another presentation on Tues, Sep 23, 2014, djw.)

Daniel J. Weidman, Ph.D.

- Dan Weidman received his Bachelor's degree in Physics from MIT in 1985, and his Ph.D. in Electrical Engineering from the Univ. of Maryland, College Park in 1995. He has authored or co-authored more than 20 journal articles and technical reports in publications and more than 60 conference presentations. He started working with electron beams more than 30 years ago, as an undergrad studying free-electron lasers and then as a grad student studying e-beam propagation through air. Experience in e-beams:
  - Food preservation, water remediation, and platelet shelf-life extension at Science Research Laboratory as a Senior Research Scientist
  - Building and testing composite-curing e-beam systems at Electron Solutions, Inc. and then installing them at NASA MSFC and Boeing Radiation Effects Laboratory
  - Scanning electron microscopes at KLA-Tencor, as a Systems Design Engineer
  - Metallization of semiconductor wafers by physical vapor deposition at NEXX Systems, Reliability Engineer
  - e-beam emitter design and manufacturing at Advanced Electron Beams, as the Principal Process Engineer
  - Dr. Weidman has since been working at MIT Lincoln Laboratory as a member of the Technical Staff.

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Thank you

Reliability of a high-power electron-beam accelerator: A Federal case

Dr. Daniel J. Weidman

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