SEC-00256 Pinellas Plant Technical Overview

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Advisory Board on Radiation and Worker Health

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Overview

- Technical Basis Documents for Pinellas
- Site Activities and Products
  - Neutron generator production and testing
  - RTG production and testing
  - Other production
- Radiation Sources
  - Radioactive materials
  - Radiation generating devices

Technical Basis Documents

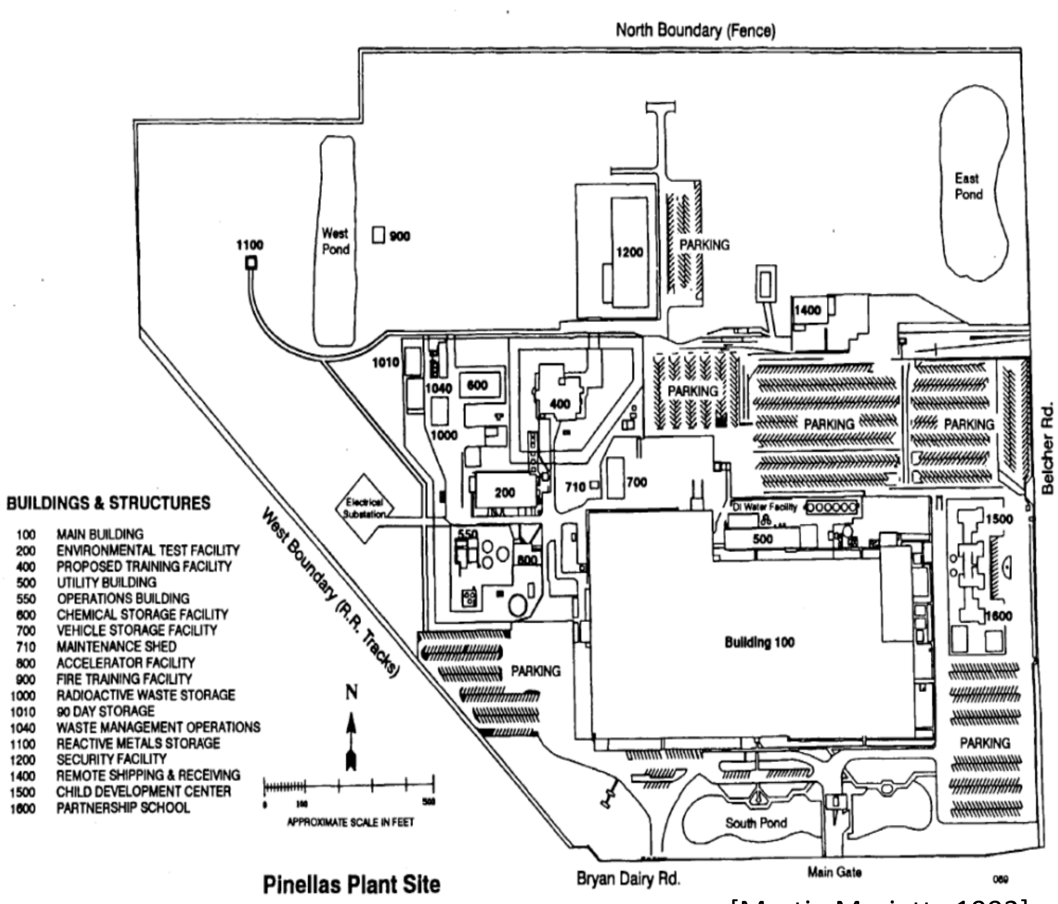
Pinellas Technical Basis Documents

Document No.	Rev.	Title	Date	Reference
ORAUT-TKBS-0029-1	01	Introduction	4/18/2011	www.cdc.gov/niosh/ocas/pdfs/tbd/pine1-r1.pdf
ORAUT-TKBS-0029-2	02	Site Description	4/1/2011	www.cdc.gov/niosh/ocas/pdfs/tbd/pine2-r2.pdf
ORAUT-TKBS-0029-3	01	Occupational Medical Dose	10/13/2011	www.cdc.gov/niosh/ocas/pdfs/tbd/pine3-r1.pdf
ORAUT-TKBS-0029-4	01	Occupational Environmental Dose	7/15/2011	www.cdc.gov/niosh/ocas/pdfs/tbd/pine4-r1.pdf
ORAUT-TKBS-0029-5	03	Occupational Internal Dose	7/18/2016	http://www.cdc.gov/niosh/ocas/pdfs/tbd/pine5-r3.pdf
ORAUT-TKBS-0029-6	02	Occupational External Dose	12/11/2017	http://www.cdc.gov/niosh/ocas/pdfs/tbd/pine6-r2.pdf -

Site Activities and Products

Pinellas Site Activities and Products

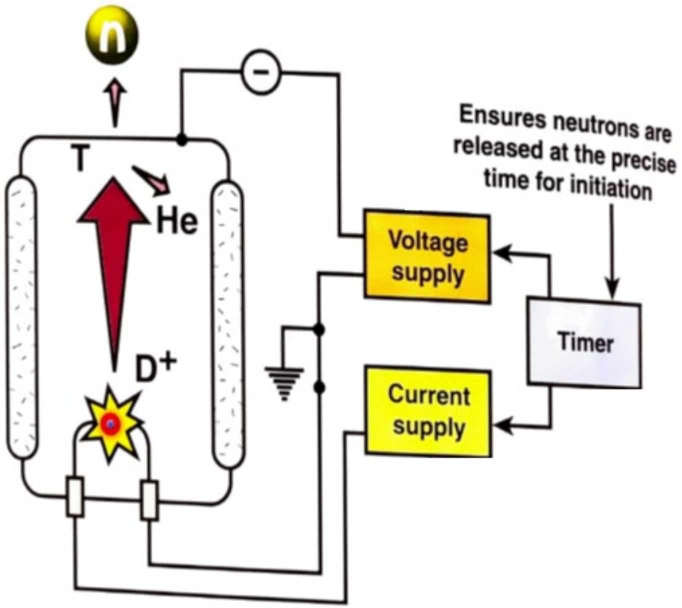
- Neutron generators
  - Production
  - Testing
- Radioisotope thermoelectric generators (RTGs)
  - Production
  - Testing
- Other products



[Martin Marietta 1993]

Site Products - Neutron Generators

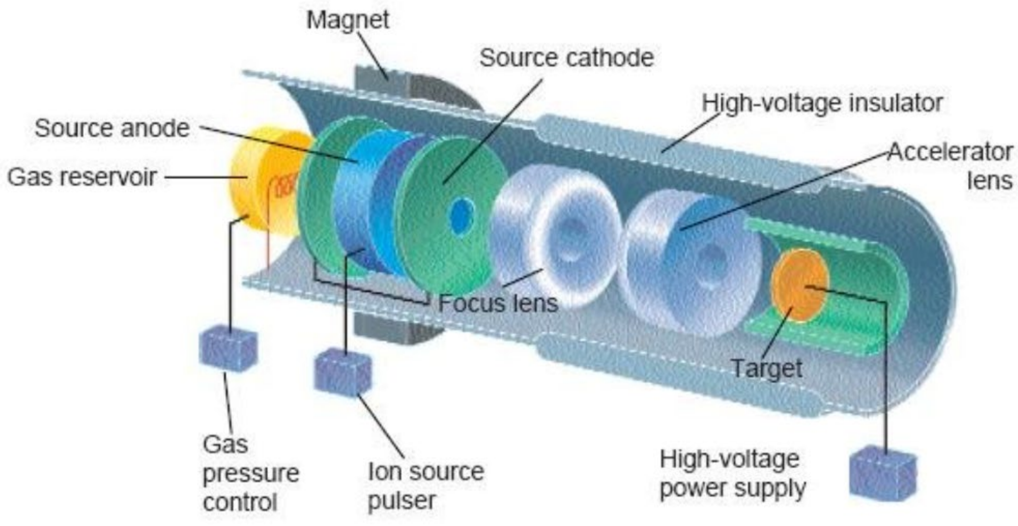
- Provide high-energy neutrons to initiate nuclear weapons and test devices.
- Miniaturized linear ion accelerator
  - A pulsed electric power supply accelerates deuterium nuclei into either a tritium or deuterium target.
  - Controlled fusion reaction produces neutrons.



[ORAUT 2011b, document pp. 16-17; Loeber 2002]

Neutron Generator Production (1 of 2)

- NG tube production involves loading metal films with deuterium and tritium under vacuum conditions to form metal hydrides.
- Metal tritides (MTs) are metal hydrides used for capturing or storing tritium gas.
- NGs contain an MT target and metal hydride deuterium gas reservoir.



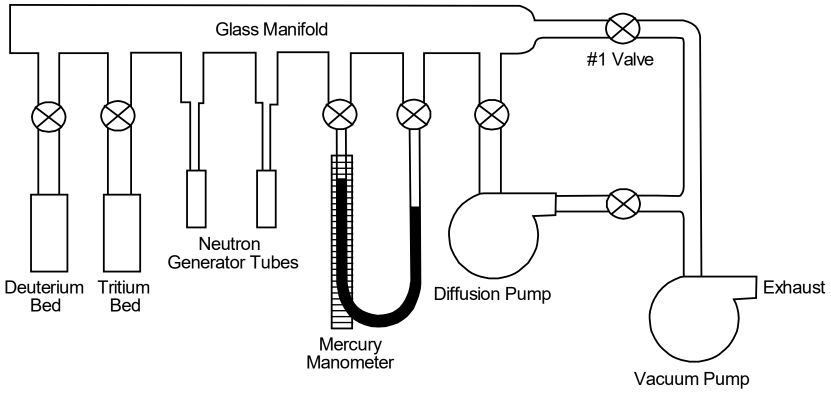
[ORAUT 2011b, document p. 14; ORAUT 2016, document p. 9; Chichester and Simpson 2003]

Neutron Generator Production (2 of 2)

- MTs were formed by reacting tritium gas with metal surfaces, thin metal coatings, and metal powders.
- Primary MTs at Pinellas were scandium tritide, erbium tritide, and titanium tritide.

Neutron Generator Production (1957-1967)

- Target material deposited as vapor onto ceramic or metal target substrate
- Targets loaded in the neutron tubes
- Neutron tubes then attached to glass manifold vacuum system under exhaust hood
- Once the system reached vacuum, storage beds were heated to flood the system with deuterium or tritium gas
- A torch was used to melt the glass manifold connection, seal the neutron tubes, and cut them free of the manifold



[ORAUT 2011b, document p. 17-21]

Neutron Generator Production (1968 and after)

- Metal system replaced the glass manifold system to address breakage and contamination issues
- Stainless steel encased depleted uranium beds replaced glass-enclosed titanium beds
- Metal targets hydrided in a glovebox, prior to being installed in tube
- Once uranium hydride storage beds were no longer useful as process beds, they were stabilized by converting the pyrophoric uranium metal powder to a more stable uranium oxide for proper disposal by connecting them to the uranium bed oxidation system in Room 21 of Area 108C

[ORAUT 2011b, document p. 20]

Neutron Generator Types

There are two basic types of neutron generators:

Electronic Neutron Generators	Ferroelectric Neutron Generators
Store electrical energy in electronic capacitor	Store energy in metal or ceramic component (ferroelectric)
Energy is released by a switch	Energy is released by shattering ferroelectric with small detonator
Large, used in bomb warheads	Small, used in missile warheads
Can be used after function tests	Destroyed in function tests

[Loeber 2002]

Neutron Generator Testing

- Leak testing using Kr-85 gas system (Radiflo® and TracerFlo)
- Functional and environmental testing
  - Vibration
  - Acceleration
  - Temperature and pressure cycling
  - Mechanical shock
- Destructive testing – debris was sorted, examined, and disposed
  - Spin testing
  - Boom box testing

[ORAUT 2011b, document pp. 20, 24]

Neutron Generator Spin Testing

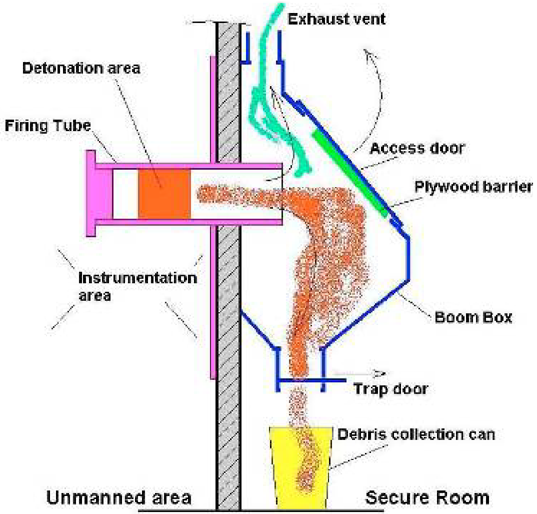
Spin testing unit was like a large top loading washer.

- The neutron generators were wired and assembled in a hard plastic material fixture and inserted into a heavy aluminum fixture.
- The very heavy lid on top of the equipment was closed.
- The workers left the secured room and detonated the neutron generator.
- There was no direct vent for this equipment other than the room's ventilation.

[ORAUT 2011b, document p. 24-25]

Neutron Generator Boom Box Testing

- The neutron generator was wired and assembled in a urethane foam fixture and inserted into the firing tube.
- The tube was closed, and the area was cleared before the neutron generator was detonated.
- After the detonation, a debris collection can was placed under the boom box.

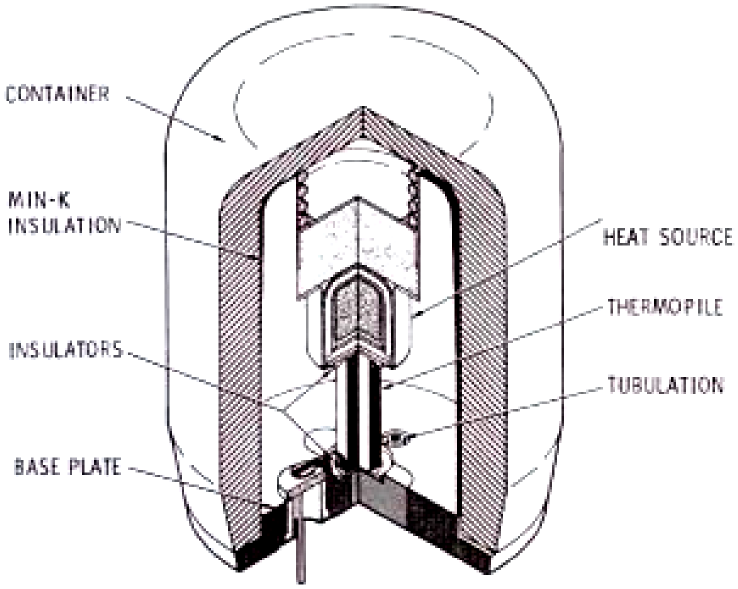


Firing Tubes and "Boom Box" configuration
(no scale)

[ORAUT 2011b, document p. 25-26

Site Products - RTGs

- RTGs are used to provide a long-life source of relatively low-energy electric power.
- An RTG consisted of:
  - Sealed heat source containing a small amount of $^{238}PuO_2$ (manufactured at another site)
  - Thermopile (manufactured at the Pinellas Plant)
  - Enclosed in thermal insulation and packaged in a welded steel case



[ORAUT 2011b, document p. 21]

RTG Production (1 of 3)

- Production occurred 1975-1990
- Produced 50 units per month
- Plutonium heat source delivered to Building 400
- Packages opened in fume hood and surveyed for contamination
  - If the unpacking survey showed >200 dpm
    - Source immediately repackaged and returned to the supplier

      NOTE: This level of contamination was never detected.
  - If the survey showed detectable contamination <200 dpm
    - Source decontaminated in accordance with procedures

[ORAUT 2011b, document p. 23; ORAUT 2016, document p. 11]

RTG Production (2 of 3)

- When pulled from storage for use:
  - Transferred to inspection hood
  - Surveyed
  - Cleaned with alcohol
  - Transferred to assembly glovebox
- Assembly performed in glovebox
- Final assembly welded with electron beam welder

[ORAUT 2011b, document p. 23]

RTG Production (3 of 3)

- After assembly:
  - Leak check and contamination survey prior to removal from glovebox
- Testing of completed assembly:
  - Dimensioning
  - Electrical input
  - Temperature
  - Vibration
  - Shock
- After testing:
  - RTG units awaiting shipment were stored in vault room

[ORAUT 2011b, document p. 23]

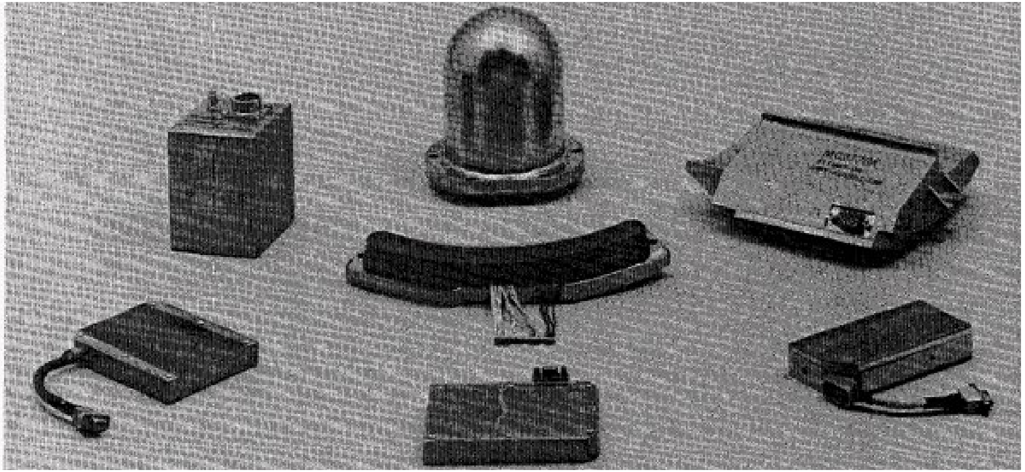
Other Products (Nonradiological)

- Neutron Detectors
- Vacuum Switch Tubes
- Specialty Capacitors
- Thermal Batteries
- Electromagnetic Devices
- LAMB Batteries
- Frequency Control Devices
- Quartz Digital Accelerometer
- Optoelectronics
- Lightning Arrest Connectors
- Mechanical Ceramics
- Ferroelectric Ceramics
- Foam Support Pads

[ORAUT 2011b, document p. 8; GE 1990]

Nonradiological Products – Neutron Detectors

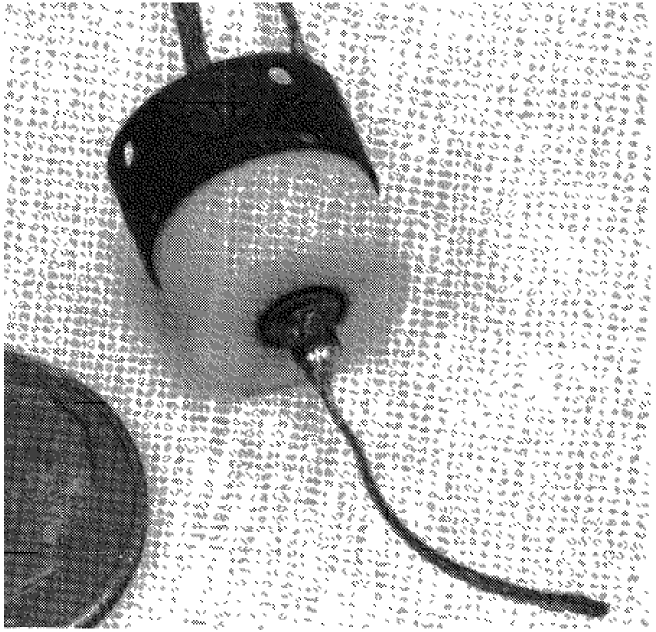
- Small electronic assemblies used to verify neutron generator output
- Used in ‘joint test assemblies’



[GE 1990, PDF p. 24, document p. 15]

Nonradiological Products – Vacuum Switch Tubes

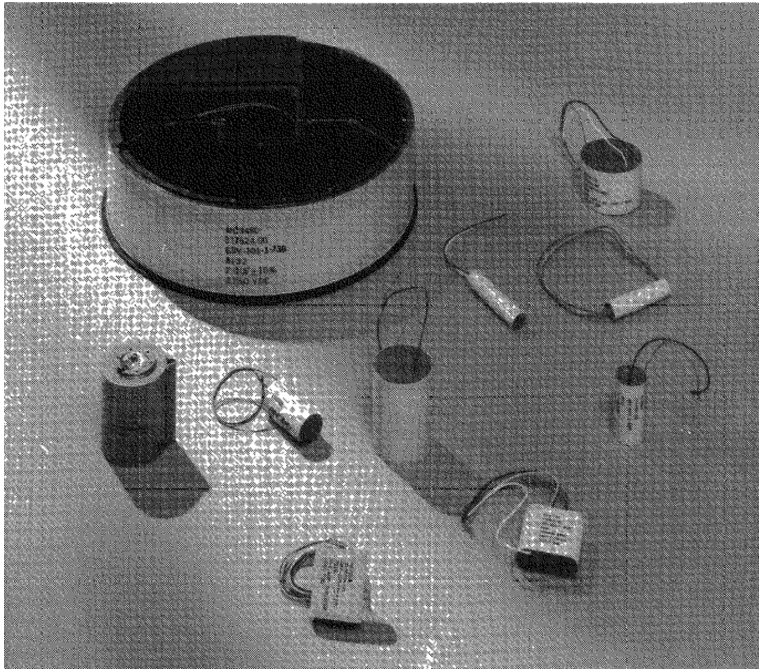
- High vacuum gaps capable of holding off 10,000 volts
- Placed in conducting condition by a small amount of energy
- Conduct 200 amperes for about 10 microseconds



[GE 1990, PDF p. 24, document p. 15]

Nonradiological Products – Specialty Capacitors

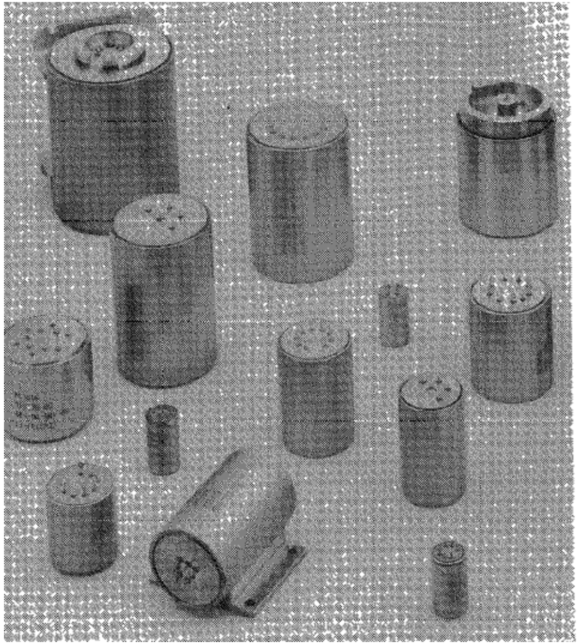
- Used to store electrical energy
- More than a dozen designs produced at Pinellas



[GE 1990, PDF p. 25, document p. 16]

Nonradiological Products – Thermal Batteries

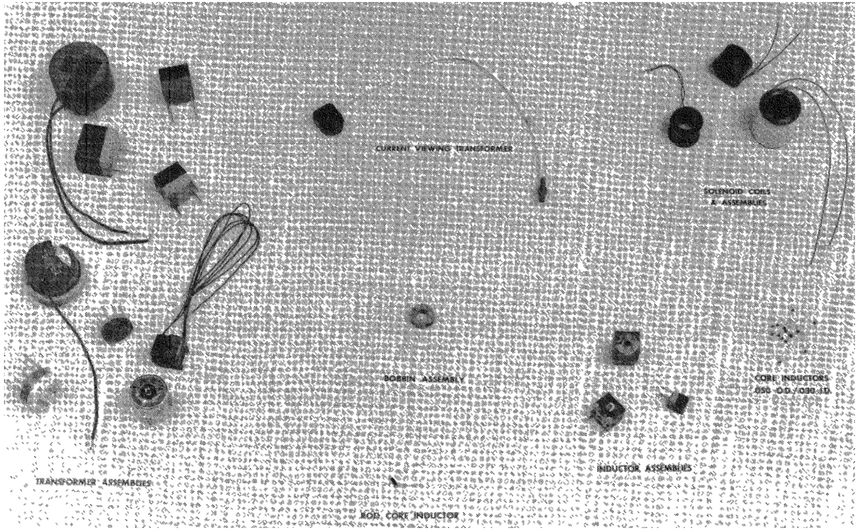
- Inactive at room temperature
- Activated by ignition of exothermic reaction
- Very long, nondeteriorating shelf life



[GE 1990, PDF p. 27, document p. 18]

Nonradiological Products – Electromagnetic Devices

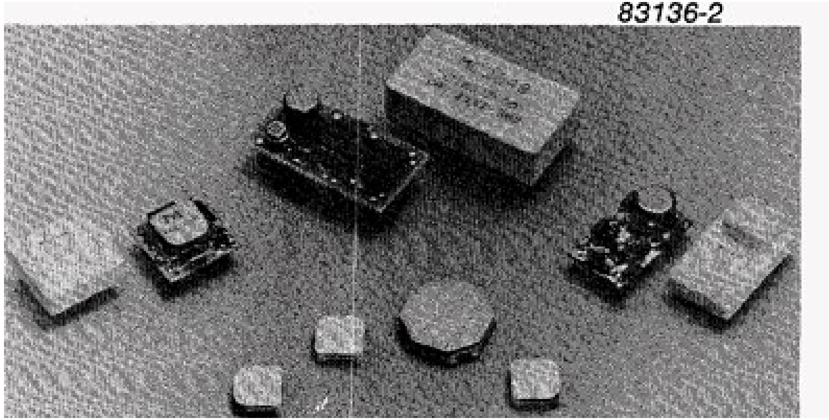
- Used to perform various functions:
  - pulse shaping
  - filtering
  - voltage and current conversion
  - current monitoring
  - activation of mechanical devices



[GE 1990, PDF p. 26, document p. 17]

Nonradiological Products – Frequency Control Devices

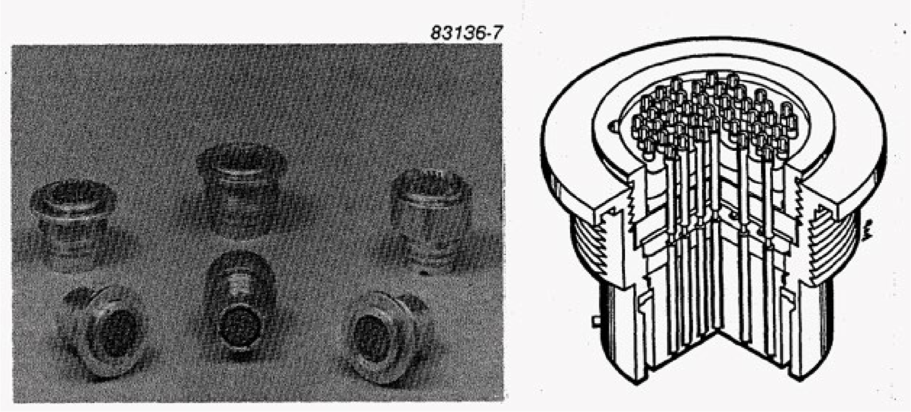
- Quartz crystal resonators and clock oscillators made for various weapons applications
- Pinellas was selected for manufacture due to existence of high vacuum, cleanliness control and ceramic production equipment



[GE 1990, PDF p. 29, document p. 20]

Nonradiological Products – Lightning Arrester Connectors

- Used to protect weapons against accidental detonation in the event of a lightning strike
- Pinellas produced more than 15 models



[GE 1990, PDF p. 33, document p. 23]

Radiation Sources

Radiation Sources – Uses at Pinellas

1. As part of a product
   - tritium (H-3) in neutron generators
   - plutonium in radioisotopically-powered thermoelectric generators (RTG)
   - uranium in certain borosilicate glass products
2. For leak-testing certain products
   - Kr-85
3. For tritium storage
   - depleted uranium in sealed containers
4. For instrument and dosimeter calibrations and checks
5. As analytical standards for laboratory analyses
   - plutonium and tritium analyses of urine samples

[ORAUT 2011b, document p. 14]

Radiation Sources – Dispersible Versus Nondispersible

- Dispersible
  - H-3
  - C-14
  - Kr-85
  - radionuclides used as analytical standards
- Nondispersible
  - plated sources
  - containerized sources
  - encapsulated sources
  - solid metal sources

[ORAUT 2011b, document p. 14]

Radiation Sources – Internal Dose Concerns

Internal dose concerns:

- Tritiated water (HTO)
- Tritium gas
- Organically bound tritium (OBT)
- Metal tritides (MT)

Not internal dose concerns:

- Kr-85 (noble gas)
- Plutonium (encapsulated RTG source)
- Uranium (contained in tritium storage and borosilicate glass)
- C-14 (negligible quantity used in labeling)
- Ni-63 (contained in vacuum tubes)
- Cs-137 and other sealed sources
- Radiation Generating Devices

[ORAUT 2011b, 2016]

Radiation Sources – External Dose Concerns

External dose concerns:

- Kr-85 (noble gas)
- Plutonium (encapsulated RTG source)
- Cs-137 and other sealed sources
- Radiation Generating Devices

Not external dose concerns:

- HTO
- Tritium gas
- OBT
- MTs
- Uranium (contained in tritium storage and borosilicate glass)
- C-14 (negligible quantity used in labeling)
- Ni-63 (contained in vacuum tubes)

[ORAUT 2011b, 2017]

Radiation Sources - Tritium

- Half-life of 12.28 years
- Low-energy, beta-emitting radionuclide, with average beta particle energy of 5.7 keV and maximum beta particle energy of 18.6 keV
- Not considered an external radiation hazard because the beta particles have too low of an energy to penetrate human skin
- Between 1957 and 1993, annual inventories at Pinellas ranged from 5.44 g - 53.27 g (5.24×10^4 Ci - 5.14×10^5 Ci)
- Predominant tritium exposure hazard to the workers was from HTO and HT. However, in some circumstances workers might have also been exposed to OBT compounds and MTs.

[ORAUT 2011b, document p. 14]

Radiation Sources - Organically Bound Tritium

- Contaminated pump oils
  - Turbo and vacuum pumps required periodic maintenance, including changing the oil
  - In tritium areas, tritium could contaminate the pump oil “through small liberations during process operations”
  - One of the most common sources of OBT
- Organic solvents (e.g., alcohol, toluene, acetone)
  - Used in the tritium areas for cleaning and degreasing tritium contaminated components

[ORAUT 2011b, document p. 9; ORAUT 2016, document p. 16]

Radiation Sources - Metal Tritides

- MTs could have been released in the work environment as particulate aerosols during production processes.
- Only a small portion of the worker population had exposure potential to a dispersible form of MT, typically limited to accidents involving MTs.

Radiation Sources – Plutonium (1 of 2)

- Pu-238 and Pu-239 are alpha and X-ray-emitting radionuclides.
- Half-life of Pu-238 is 87.75 years.
- Half-life of Pu-239 is 24,131 years.
- Alpha particle emissions are primary concerns for internal dose.
- Photon (gamma ray and X-ray) and neutron radiation emitted from the sources containing plutonium are primary concerns for external dose.

[ORAUT 2011b, document p. 15]

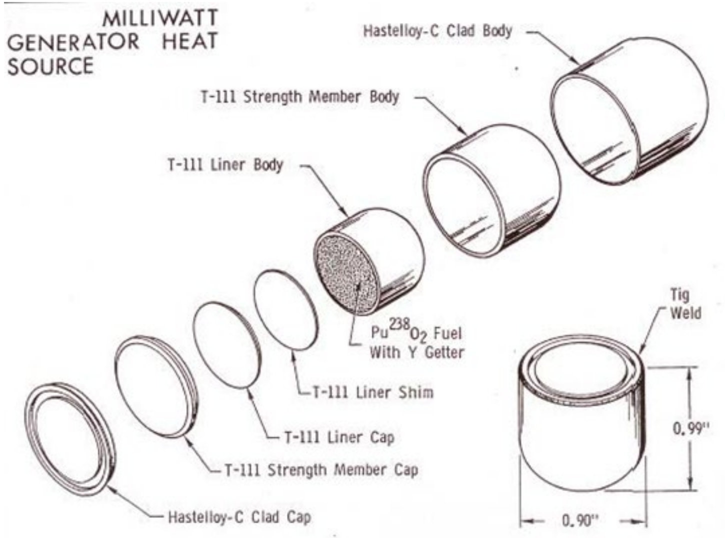
Radiation Sources – Plutonium (2 of 2)

- First plutonium at the Pinellas Plant was a 7-g Pu-239 source received in January 1957.
  - Used for calibrating health physics monitoring equipment.
  - Encapsulated plutonium-beryllium (Pu-Be) based on site records.
- The Pinellas Plant also had several small plutonium sources that were used as alpha check sources for instruments.
- Pu-238 (for RTG program) was received starting in 1975.

[ORAUT 2011b, document p. 15; ORAUT 2017, document p. 11]

Radiation Sources – Plutonium (RTG)

- Two different heat sources were used in the RTG units:
  - 8.75 g plutonium dioxide
  - 10 g plutonium dioxide
- Configuration of both types is the same:
  - triple encapsulated
  - outer layer was nickel alloy
  - two inner layers were a tantalum alloy
- Predominantly composed of Pu-238 with significantly smaller percentages of other Pu isotopes, decay products, and radioactive impurities.



[ORAUT 2011b, document p. 21]

Radiation Sources – Kr-85 (1 of 2)

- Noble gas
- Beta-emitting radionuclide
- Half-life of 10.72 years
- Average beta particle energy is 251.4 keV and maximum beta particle energy is 687.0 keV

[ORAUT 2011b, p. 15]

Radiation Sources – Kr-85 (2 of 2)

- Relatively small quantities of Kr-85 were used at Pinellas in two leak detection systems (Radiflo® and TracerFlo systems) from 1963 to 1996.
- Systems were housed in separate rooms in Area 109 and surrounded by ventilation shrouds. Each shroud was connected to ductwork that exhausted to the east main exhaust stack.
- During 1996, this equipment was decontaminated and relocated to Building 800, along with unused storage containers of Kr-85 gas.
- By the end of 1996, all leak detection equipment and unused cylinders of Kr-85 gas were shipped back to their manufacturers.

Radiation Sources – Uranium

- Depleted and natural uranium were present at Pinellas.
- They consist of U-234, U-235, U-238 and some of the radioactive progeny for these radionuclides.
- Uranium isotopes emit alpha particles and X-rays.
- Some of the radioactive progeny emit beta particles and gamma rays.

[ORAUT 2011b, document p. 15]

Radiation Sources – Depleted Uranium

- Sealed in stainless-steel canisters in the tritium storage beds (first used in 1968)
- No indication that uranium ever leaked from the containerized storage beds
  - None of the reported incidents for the Plant were uranium releases or uranium fire incidents (Table 2-4 of ORAUT 2011b)

[ORAUT 2011b, pp. 15-16]

Radiation Sources – Natural Uranium

- Primarily present in borosilicate glass doped with natural uranium (1.5% by weight) in the form of U_3O_8
- Encapsulated in glass prior to arrival at the Plant
- Considered a sealed source and posed little to no internal dose hazard

[ORAUT 2011b, document pp. 15-16]

Radiation Sources – Nickel-63 (1 of 2)

- Low-energy, beta-emitting radionuclide
- Half-life of 100.1 years
- Average beta particle energy is 17.13 keV
- Maximum beta particle energy is 65.87 keV

[ORAUT 2011b, document p. 16;
ORAUT 2016, document p. 12]

Radiation Sources – Nickel-63 (2 of 2)

- Used in cold-cathode, gas-filled tubes (krytrons) used as very-high-speed switches
- US Radium electroplated Ni-63 onto a nickel mesh (averaged 0.3 µCi per spark gap).
- Available information indicates that the Plant was not involved in the electroplating process.
- Pinellas likely sealed the electroplated ^{63}Ni electrodes into the glass tubes to create the krytron. One of the Plant’s areas of expertise was glass formulation.

[ORAUT 2011b, document p. 16]

Radiation Sources – Carbon-14

- Low-energy, beta-emitting radionuclide
- Half-life of 5,730 years
- Average beta particle energy is 49.47 keV
- Maximum beta particle energy is 156.48 keV
- Use of C-14 indicated only in the gaseous effluent release reports and an environmental assessment.
- 1983 environmental assessment indicated that small quantities of C-14 labeled solvents were used in a laboratory testing operation.

[ORAUT 2011b, document p. 16]

Radiation Sources – Radiation Generating Devices (1 of 3)

Neutron Generator:

- Most common type of radiation-generating device at Pinellas
- Produced neutrons
- Also produced some X-rays by other interactions within the accelerator

[ORAUT 2011b, document pp. 16-17]

Radiation Sources – Radiation Generating Devices (2 of 3)

Ion Accelerator:

- Manufactured by Accelerator Inc., and first installed in 1975 in Area 161 of Building 100 for use by the Chemistry Laboratory
- Originally used for ion implantation and later for target assessment
- Relocated in 1979 to Building 800 and used for a larger variety of activities including target assessment; material analysis; low-energy nuclear, solid-state, and atomic physics; and material science
- Personnel working with this accelerator were required to wear dosimeters that measured both photon and neutron doses (Weaver 1994b).

[ORAUT 2011b, document p. 17]

Radiation Sources – Radiation Generating Devices (3 of 3)

Other Radiation Generating Devices

- Electron Beam Welder
- Electron Microsope
- Sedigraph (particle size analysis using X-rays)
- Other equipment containing X-ray generators (X-ray diffraction, cabinet X-ray machines, thickness gauges, etc.)

[ORAUT 2011b, document p. 18]

References

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