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# FLASH X-RAY FACILITY





Naval Surface Weapons Center
White Oak Laboratory

WEAPON SYSTEMS FOR THE FLEET
NSWC

# FLASH X-RAY FACILITY



Naval Surface Weapons Center,
White Oak Laboratory
Silver Spring, Maryland 20910

AUGUST 1977

**UNCLASSIFIED**

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This publication provides information for the convenience of potential users of the Flash X-Ray Facility located at the Naval Surface Weapons Center, White Oak Laboratory. These flash x-ray machines provides the nuclear weapon effects community with the capability of simulating those effects in materials, electronic components, and circuits which are caused by the gamma ray output from a nuclear weapon. Included in this publication is information on the operating characteristics of the Febetron 705 and 706 flash x-ray machines, support capabilities, dosimetry, instrumentation, and travel.

# FLASH X-RAY Facility

Table of Contents

Chapter 1

# INTRODUCTION

In order for engineers and scientists to study the effects of nuclear radiation on electronics, it has been necessary for the nuclear weapons effects community to develop and learn to use a diverse and sophisticated family of radiation effects simulators. Pulsed fission reactors are the most often used simulators for studying the effects of fast neutrons on electronic components and circuits, while flash X-ray machines are the primary radiation sources used to simulate and study the various gamma ray effects.

This brochure outlines the flash x-ray simulators and special facilities in use at the Naval Surface Weapons Center, White Oak Laboratory (NSWC/WOL). It also lists other simulators available within a short drive of the WOL facilities.

The White Oak Laboratory Flash X-Ray Facility is located on the ground floor of the Nuclear Vulnerability and Hardening (V&H) Building. The V&H building is adjacent to the DNA CASINO Facility. The CASINO Facility is a special giant, flash X-ray machine, which is operated and maintained for DNA by NSWC, the Navy's lead nuclear weapons effects laboratory. Located on ground adjacent to the rear of the White Oak Laboratory is the DNA-AURORA Facility. AURORA is part of the Army's Harry Diamond Laboratories complex. The Naval Surface Weapons Center's Nuclear Vulnerability & Hardening Facility, the Army's Harry Diamond Laboratories, and the CASINO and AURORA Facilities, form a major center for nuclear radiation testing east of the Mississippi. Such a center is conducive to major theoretical programs which require experimental testing.

Chapter 2

## NSWC TRANSIENT RADIATION EFFECTS SIMULATORS

### WHITE OAK LABORATORY FLASH X-RAY FACILITY

*Flash X-Ray* machine is the name applied to that family of radiation generators which are capable of producing an intense pulse of gamma-type bremsstrahlung radiation. The radiative output of these machines is produced by stopping a pulsed electron beam in some high Z target material, usually tungsten or tantalum. The electron beam is normally generated by the discharge of a capacitor bank, such as a Marx generator, into a cold cathode field emission tube. With the targeting material removed, the electron beam can be used directly to simulate certain other effects produced by nuclear radiation. The radiation produced by the flash x-ray machine can, depending on its rate of generation, total dose, energy, and exposure area, be used to study the various effects on electronic components and circuits, such as photocurrent generation, circuit upset, ionization effects, etc.

The NSWC White Oak Laboratory is currently operating three flash X-ray machines: two Febetron 705s, and one Febetron 706. A floor plan of the test facility is shown in Figure 1. One of the Febetron 705 machines is equipped with an external electron beam concentrator for special electron beam studies. The electron beam concentrator can develop electron energy densities up to 120 cal/cm$^2$ over 1 cm$^2$ in a reduced air pressure environment. This machine is also equipped with a water-cooled magnetic focusing system, which allows the machine to fast fire once every 45 seconds. The other Febetron 705 is capable of firing once every 4 minutes. A brief description of these machines follows.

**Febetron 705.** A photograph of the Febetron 705 and a description of its normal output characteristics are presented in Figure 2. A schematic layout of the fast fire Febetron 705 in its exposure room is shown in Figure 3. Figure 3 also details nominal lengths required for instrumentation cables running from the exposure area to the RF instrumentation room.

The Marx generator in the Febetron 705 may be charged over a voltage range from 10 kV to 35 kV, which in turn will generate electrons with energies ranging from 600 kV to 2.3 MV, respectively. The discharge voltage can be adjusted continually over the operating range by changing both the charging voltage and the gas pressure of the containment tank.

# FLASH X-RAY Facility

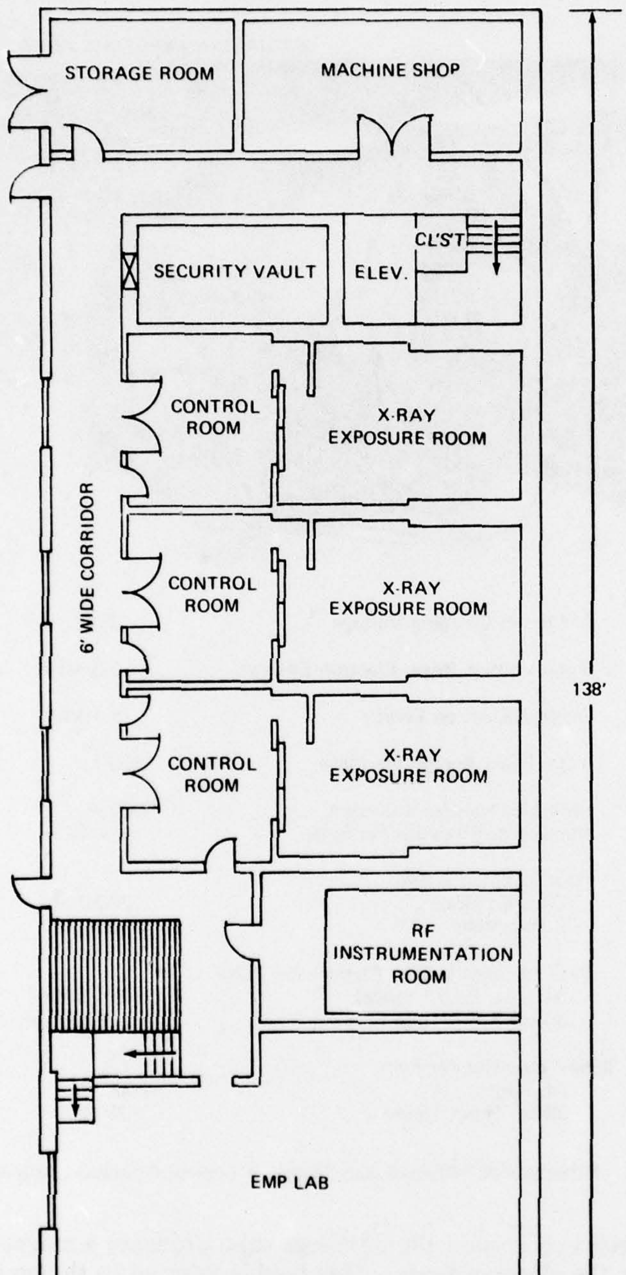
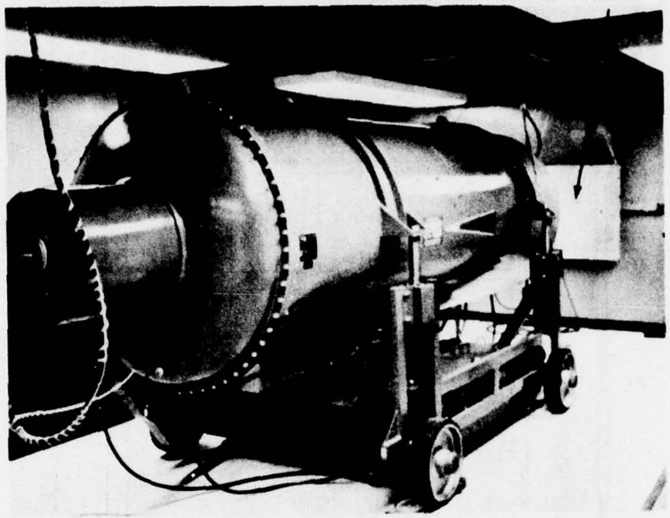



**Figure 1 Plan View of NSWC (WOL) Flash X-Ray Facility**

# FLASH X-RAY Facility




| | |
|---|---|
| Maximum Charging Voltage | 35 kV |
| Tube Voltage (Max. Electron Energy) | 2.3 MeV |
| Average Electron Energy | 1.4 MeV |
| Total Beam Energy Per Pulse | 400 J |
| Peak Electron-Beam Current | 5000 A |
| Number of Electrons Per Pulse | $\sim 2 \times 10^{15}$ |
| Pulse Width (FWHM) | |
| Electron Mode | 20-50 ns |
| X-Ray Mode | 20 ns |
| Peak Electron Energy Fluence Per Pulse | |
| At Tube Face (Anode) | $\sim$25 cal/cm$^2$ |
| 30 cm From Tube Face | $\sim$0.1 cal/cm$^2$ |
| X-Ray Intensity Per Pulse | |
| At Target | $\sim$7000 R |
| 30 cm From Target | $\sim$25 R |

**Figure 2 Febetron 705 Flash X-Ray Machine Typical Operating Characteristics**

A magnetic coil around the discharge tube produces a magnetic field which focuses the electron beam. This field is internal to the containment tank and permeates the external exposure area. This external dc magnetic field occurs prior to and along with the gamma pulse and is between 10 and a couple hundred gauss in magnitude with the largest strength being directly in front of the target plate of the machine. The experimenter should be aware of the presence of this magnetic field and its possible relationship to experimental apparatus.

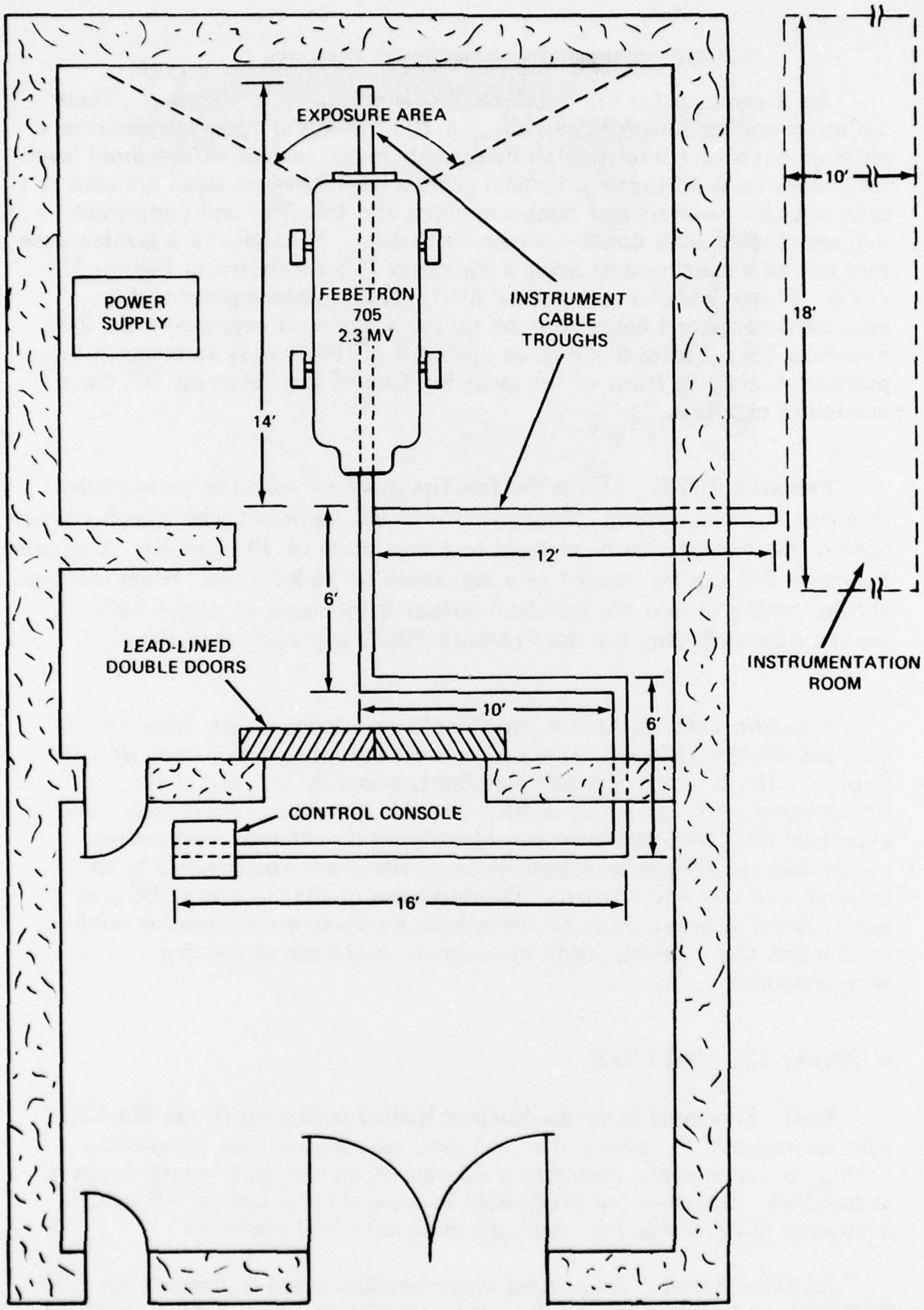



**Figure 3 Typical Flash X-Ray Room Layout**

# FLASH X-RAY Facility

An X-ray map for the Febetron 705 is presented in Figure 4. There are many applications for the Febetron 705. Some of these are measurement of diode and transistor photocurrents, measurement of threshold levels for gamma-induced turn-on, tactical gamma level upset of small systems, such as radio receivers and minicomputers, and transient and permanent damage studies using direct electron irradiation. Examples of a gamma dose rate test of a small system using a Febetron 705 are shown in Figures 5 and 6. Figure 5 shows a complete AN/UYK-20 minicomputer and its associated peripheral equipment set up for a low level exposure from the Febetron 705. Figure 6 shows an open AN/UYK-20 with its memory in position directly in front of the radiation face of the Febetron 705 for a maximum exposure.

Febetron 705-X. This is the fast fire machine with the water-cooled magnetic focusing system. This machine is also equipped with a high voltage option that allows it to be charged to a maximum of 40 kilovolts. A regular Febetron 705 can be charged to a maximum of 35 kilovolts. When this high voltage option is used the radiation output is increased by about 50%. A gamma dose field map for the Febetron 705-X is presented in Figure 7.

Febetron 706. A picture and the characteristics of the Febetron 706 are presented in Figure 8. Despite its small output and exposure area, the Febetron 706 is a very valuable simulator, primarily because of its extremely short (3 ns) pulse width. For this reason it is frequently used in experimentally tracking down and identifying the damage mechanisms responsible for failures sustained by small electronic components in an underground test environment. Extensive use of the Febetron 706 was made during a recent study of the radiation effects on amorphous semiconductors and a similar study on magnetic materials and plated wire memories.

## SUPPORT CAPABILITIES

Staff. Personnel from the Nuclear Radiation Branch (Code WA-52), who are assigned to operate the machines, are also available to assist in setting up experiments, performing dosimetry, and lending general support as required. Engineers knowledgeable in experimental testing and instrumentation are available for consultation on technical problems.

Instrumentation. Supporting instrumentation and equipment for conducting experiments with the flash X-ray machines are available. A partial list of this equipment follows:

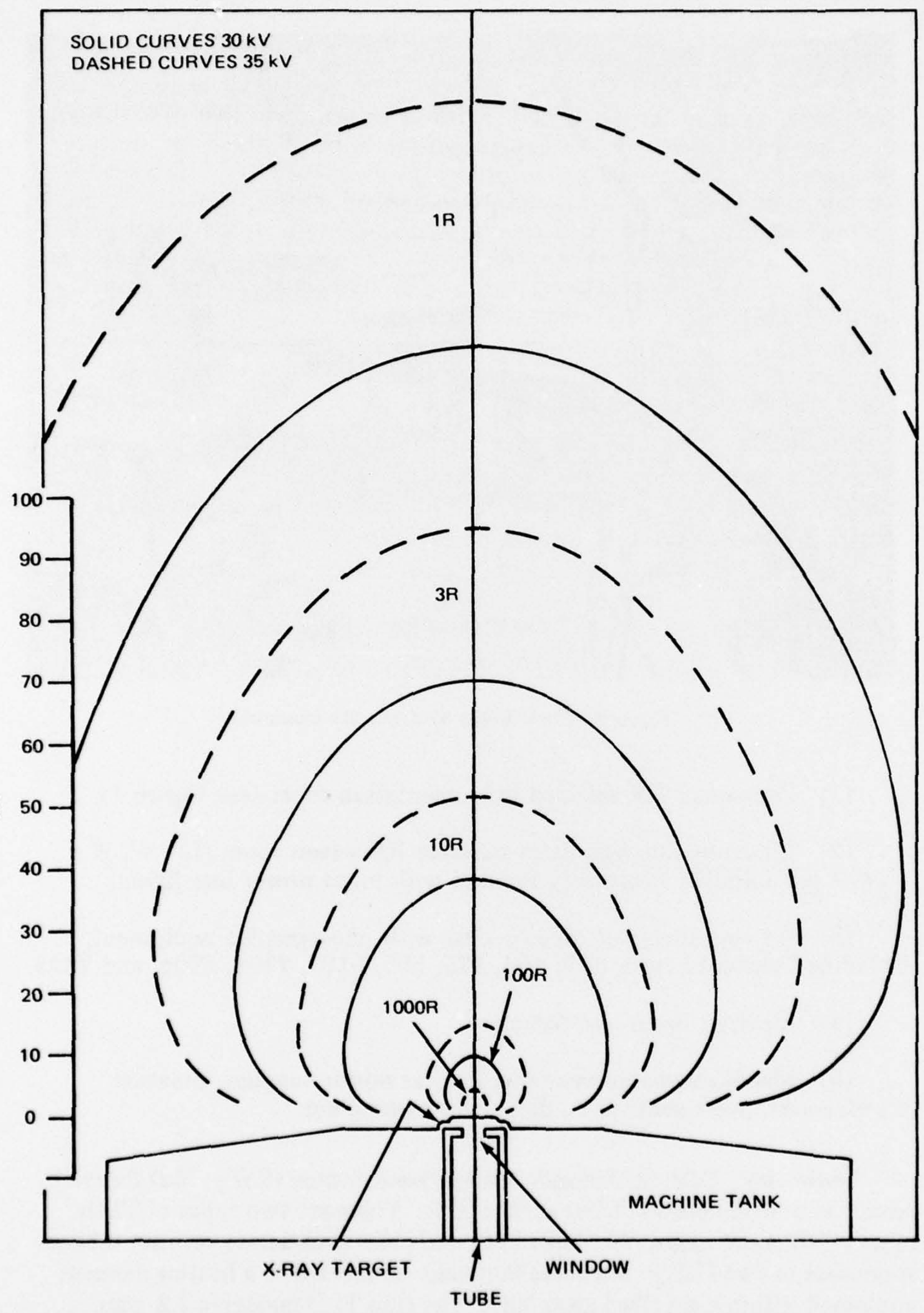



**Figure 4 X-Ray Exposure Map of Febetron 705/Tube 545C, 30 and 35 KV Incident Beams**

# FLASH X-RAY Facility

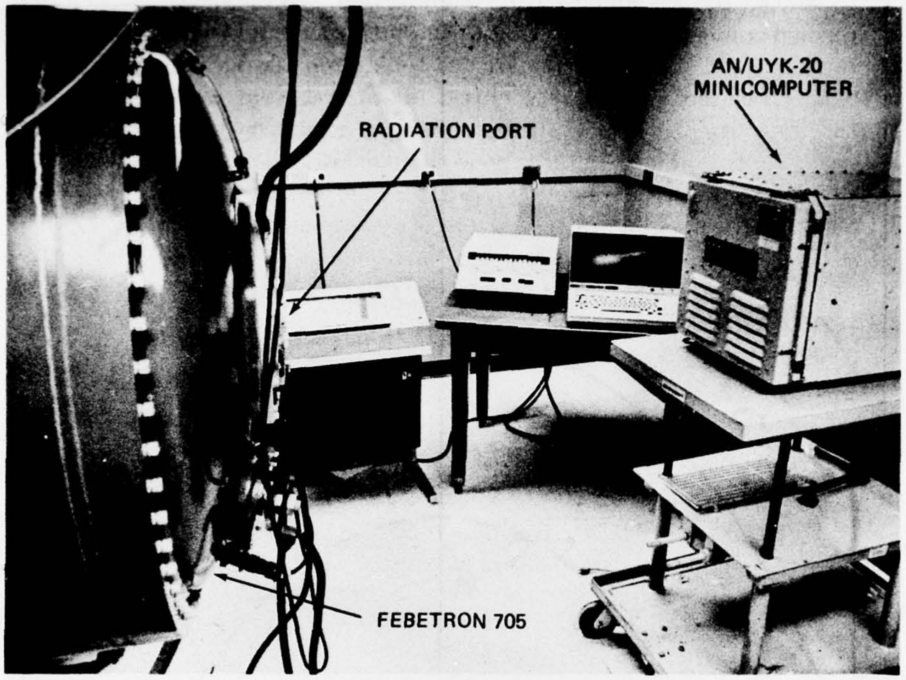



**Figure 5 Flash X-Ray Test of a Minicomputer**

(1) Permanent RF shielded instrumentation room (see Figure 1).

(2) Lindgren and Associates portable RF screen room (L = 6', W = 5', H = 6.5') double electrically isolated with input power line filters.

(3) An assortment of oscilloscopes with photographic equipment, including Tektronix types 519, 454, 475, 555, 5103, 7704, 7904, and 7623.

(4) Electron beam test fixture.

(5) Miscellaneous instruments, such as power supplies, isolation transformers, pulse generators, digital voltmeters, etc.

Dosimetry. Calcium Fluoride Manganese-activated ($CaF_2$: Mn) thermoluminescent dosimeters (TLDs) are available. There are two types of TLDs in use: bulbs and chips. The bulb TLD resembles a miniature vacuum tube. It consists of two $CaF_2$: Mn chips thermally connected to a heating element contained within a gas filled glass bulb. The chip TLD measures 3.2 mm x 3.2 mm x .9 mm. Both types have a useful dose range of .005R - 5000R. The TLDs can be read out immediately after a shot using a manual, EG&G type peak reading TLD reader.

**Radioactive Components/Hot Handling Lab.** A radioactive laboratory (Figure 9) for handling *hot* electronics and materials is located on the first floor of the V&H Facility. It is designed to Atomic Energy Commission safety specifications. Wash areas, closed air areas, storage, working, and dressing areas are provided. Any equipment or machinery assigned to the *hot* or *gray* areas remains in these areas permanently. Thus, the danger of contaminated tools reaching other laboratory areas is eliminated. The laboratory is specifically designed to allow experimenters to examine radioactive components and materials which have been exposed in reactors or become contaminated in underground tests or otherwise activated during testing.

## CONTACT

Technical and administrative inquiries about use of the NSWC Flash X-Ray Facility should be directed to:

NAVAL SURFACE WEAPONS CENTER
White Oak Laboratory
White Oak, Silver Spring, MD 20910
Attn: Code WA-52
(202) 394-2418

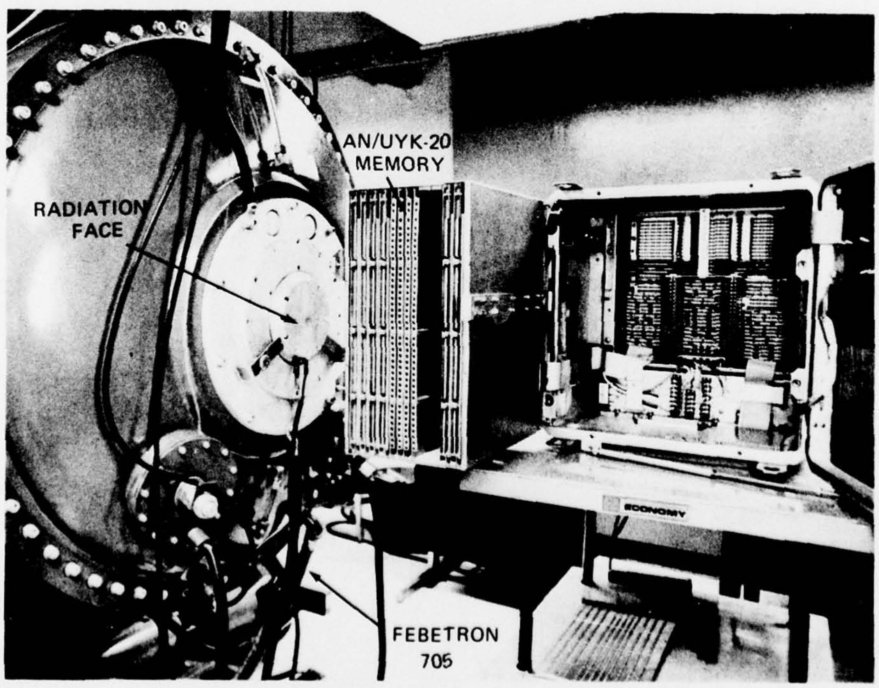



**Figure 6 Flash X-Ray Test of AN/UYK-20 Internal Memory**

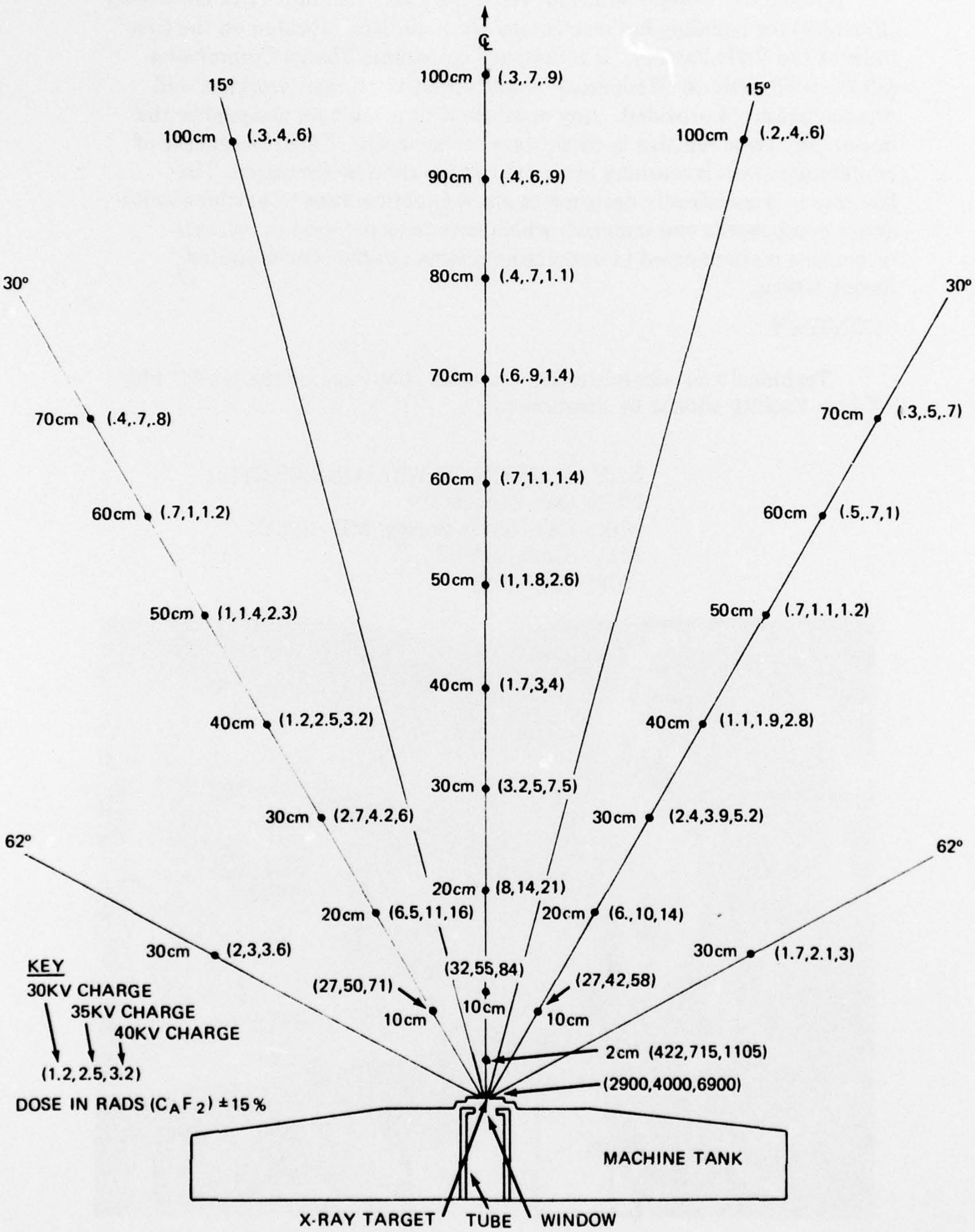
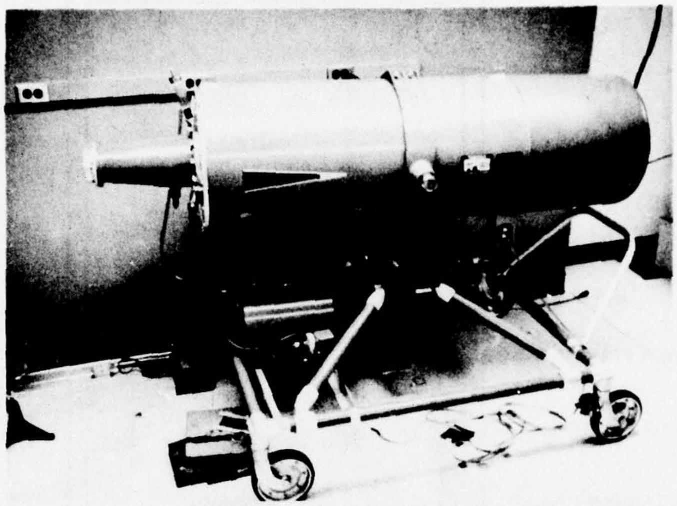



**Figure 7 Febetron 705-X Gamma Dose Field Map**

# FLASH X-RAY Facility



Electron Beam Output

| | |
|---|---|
| | Tube 5515 |
| Total Output Beam Energy | 12 joules |
| Output Current Pulse Duration (FWHM) | 3 nsec |
| Maximum Beam Energy Density (on axis, at tube face) | 8 joules/$cm^2$ |
| Surface Dose in Aluminum, 1/4" away from the face | 4 Mrads |
| Linear Extrapolated Range in A1.<br>Equivalent electron energy | 200 mg/$cm^2$<br>600 KeV |

X-Ray Output

| | |
|---|---|
| Pulse Duration (FWHM) | <3 nsec |
| X-ray dose/pulse max.<br>(just outside X-Ray target)<br>12" from tube face | <br>100 R<br>80 mR |

**Figure 8 Febetron 706 and System Specifications**

# FLASH X-RAY Facility

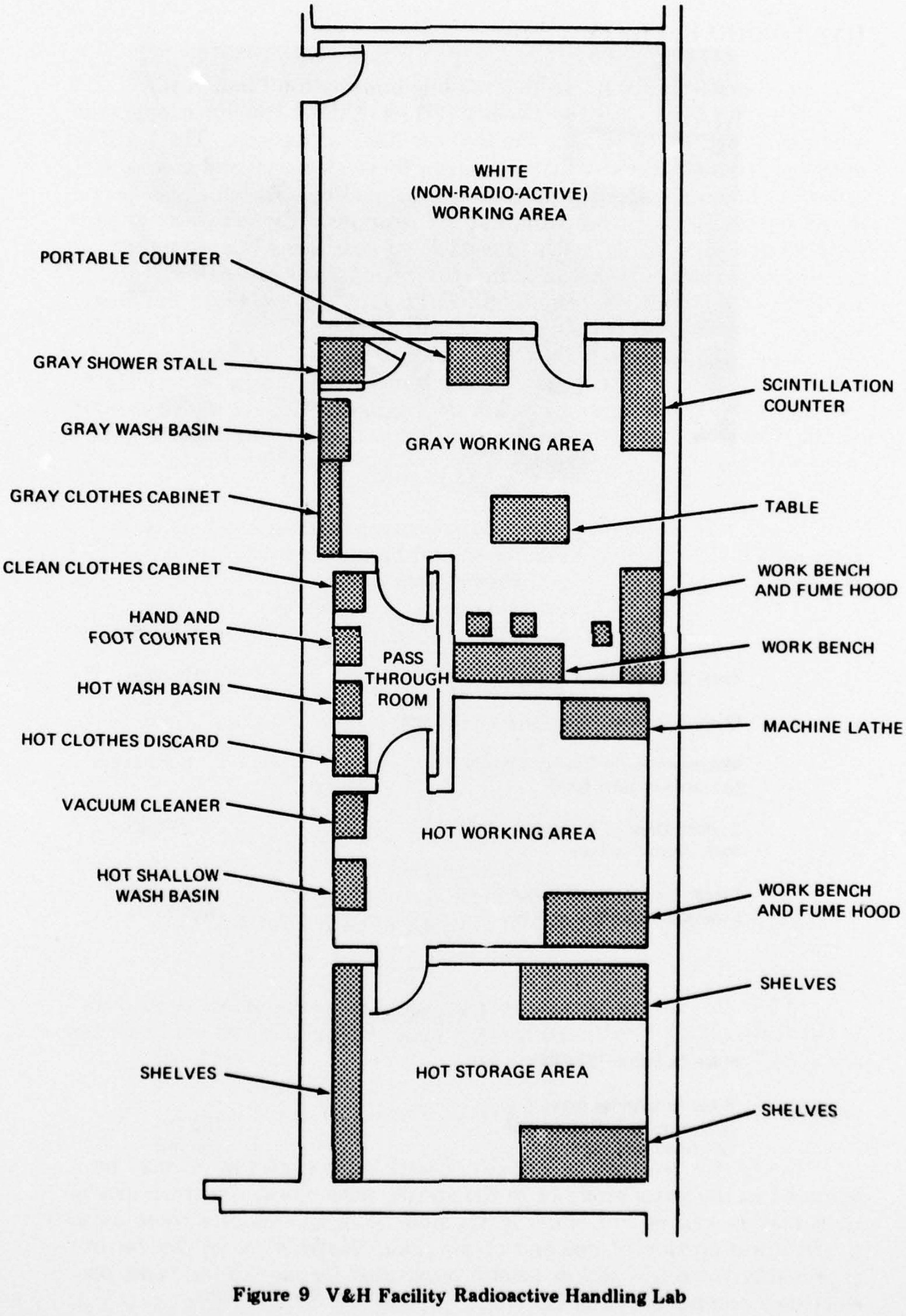



**Figure 9 V&H Facility Radioactive Handling Lab**

## DNA CASINO FACILITY

Immediately adjacent to the building housing the Flash X-Ray Facility is the DNA CASINO Facility. The CASINO Facility is operated and maintained by NSWC for the Defense Nuclear Agency. The CASINO machine is designed primarily to simulate those electrical and mechanical effects in materials, electronics components, and circuits which are produced by the X-ray output from nuclear weapons. The generator is basically a large, flash X-ray machine capable of generating intense pulses of electrons which may be used directly for materials research or converted to X-ray photons. The CASINO Facility is housed in a building which measures approximately 32,000 square feet. The facility includes general purpose staff and user laboratories, specialized examination laboratories, radiation test cell, two electrically shielded instrumentation enclosures, two computerized digital data systems (one for experiments and the other for machine diagnostics), a completely equipped dark room, an indoor area for instrumentation trailers, and a security storage vault.

Further information concerning the capabilities of the facility or requests for the use of the facility should be directed to:

Defense Nuclear Agency (DNA)
Attn: RAEV (CASINO Project Officer)
Washington, D. C. 20305
(202) 325-7026

# Chapter 3

# OTHER TRANSIENT RADIATION EFFECT SIMULATORS

NSWC also makes use of other transient radiation effect simulators in the Washington, D. C. metropolitan area. These facilities are listed below along with a short description of each.

## DIAMOND ORDNANCE RADIATION FACILITY (DORF)

The DORF reactor is a TRIGA MARK F pool reactor. It may be operated in the pulse mode or in the steady state mode. Neutron irradiations may be carried out either in the pool or in an exposure room adjacent to the lower portion of one end of the pool. NSWC's use of this facility is primarily for active and/or passive permanent damage experiments on electronic components and circuits.

# FLASH X-RAY Facility

## ARMY PULSE RADIATION FACILITY (APRF)

The APRF reactor is a bare, all metal, unreflected, and unmoderated critical assembly in the form of a right circular cylinder. The reactor is capable of operating either in a pulse mode or in a steady-state mode. As with the DORF reactor, NSWC uses the APRF reactor for neutron irradiation of electronic components and circuits.

## NATIONAL BUREAU OF STANDARDS (NBS)

The National Bureau of Standards operates a high-flux reactor. Its neutron irradiation capabilities consist of four pneumatic *rabbit* tubes, a vertical in-core thimble, and a graphite column. The former two sample the core flux and are primarily for fast neutron irradiations of short and long duration, respectively, while the latter provides a well-moderated thermal flux. Fast neutron permanent damage studies on small semiconductor components is the feature of this facility. NBS also operates a Cobalt-60 source for total dose gamma tests.

## DNA AURORA FACILITY

AURORA is a giant flash X-ray machine designed for prompt gamma system studies. It is used to expose large assemblies to threat levels. It is operated and maintained for DNA by Harry Diamond Laboratories (HDL). AURORA synchronizes the voltage output of four (4) Blumlein pulse-forming networks to produce a radiation pulse 100 ns long.

## ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE (AFRRI)

AFRRI is a radiobiological research facility. Its LINAC and Cobalt-60 source are available for TREE work. NSWC uses the LINAC primarily for transistor photocurrent measurements. The Cobalt-60 gamma well has a loading of 300,000 curies. Total gamma dose tests are easily accomplished in this facility.

## GAMBLE II

GAMBLE II is a one-of-a-kind flash X-ray machine operated by the Naval Research Laboratory (NRL). It consists of a water dielectric coaxial pulse forming line which is rapidly charged to about 7 MV in a little less than 0.2 microseconds. It discharges its energy (approximately 100 kJ) within about 50 ns through a series switch at the output end of its center conductor into a matched coaxial transmission line.

## Chapter 4

## TRAVEL INFORMATION

The Flash X-Ray Facility is located at the Naval Surface Weapons Center, White Oak, Silver Spring, Maryland. It is convenient to Washington National Airport, Dulles International Airport, and Baltimore-Washington International Airport.

- From National Airport, drive north on the George Washington Parkway to the Capital Beltway (I-495) and turn east toward Maryland.
- From Dulles, take the access road to I-495 and head north to Maryland.
- From the Baltimore-Washington International Airport, take the Baltimore-Washington Parkway toward Washington and turn north on I-495.

Once on I-495, take Exit 25 (New Hampshire Avenue North — White Oak) and proceed north on New Hampshire Avenue. Turn right into the Naval Surface Weapons Center. Users need to check in with the receptionist in the Administration Building where they will be issued a visitor's badge. During initial visits, users will be escorted to the Flash X-Ray Facility.

A partial list of motels convenient to the White Oak area follows:

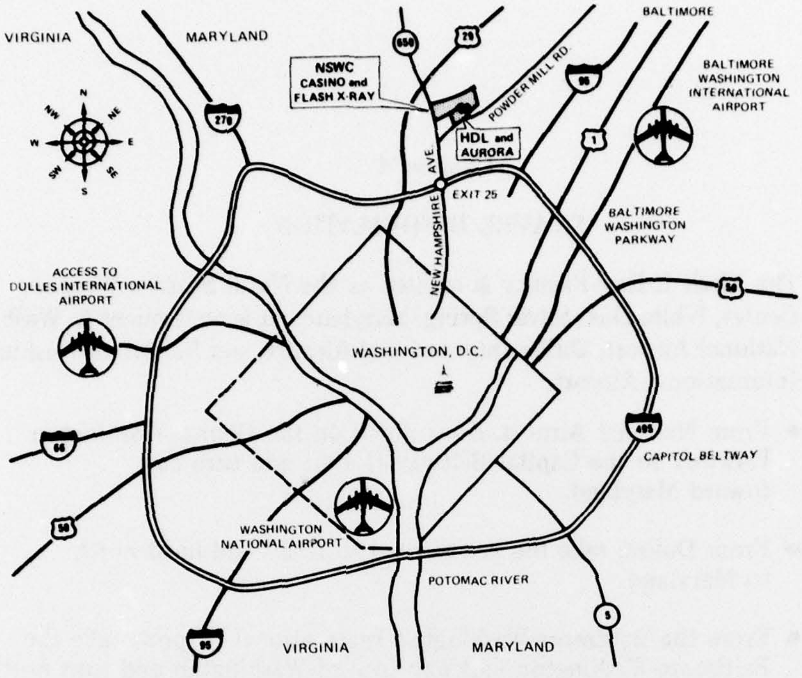
*Silver Spring — I-495, Exits 21 or 23*

Holiday Inn
8777 Georgia Avenue — 301-589-0800
Silver Spring, Maryland 20910

Sheraton Silver Spring Motor Inn
8727 Colesville Road — 301-589-5200
Silver Spring, Maryland 20910

Twin Towers
1110 Fidler Lane — 301-587-0800
Silver Spring, Maryland 20910

# FLASH X-RAY Facility




*Route 1 — I-495, Exit 27*

| | |
|---|---|
| **Colonial Plaza**<br>**10203 Baltimore Boulevard**<br>**College Park, Maryland 20740** | **301-474-5678** |
| **Del Haven**<br>**10200 Baltimore Boulevard**<br>**College Park, Maryland 20740** | **301-474-6565** |
| **Hillcrest Motor Court**<br>**9122 Baltimore Boulevard**<br>**College Park, Maryland 20740** | **301-441-2211** |
| **Holiday Inn**<br>**9137 Baltimore Boulevard**<br>**College Park, Maryland 20740** | **301-935-5000** |
| **Holiday Inn**<br>**10000 Baltimore Boulevard**<br>**College Park, Maryland 20740** | **301-345-6700** |
| **Royal Pine Motel**<br>**9113 Baltimore Boulevard 20740**<br>**College Park, Maryland** | **301-345-4900** |