Site Characterization Report
NASA GRC Cyclotron Facility
Cleveland, Ohio

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Prepared for:
NASA GRC at Lewis Field
21000 Brookpark Road
Cleveland, OH 44135

Prepared by:
Science Applications International Corp.
6100 Columbus Avenue
Sandusky, OH 44870

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1.0 EXECUTIVE SUMMARY

This report presents results of the site characterization survey of the National Aeronautics and Space Administration (NASA) Cyclotron Facility located in Building 140 at Glenn Research Center (GRC), Lewis Field, in Cleveland, Ohio. This report describes the Cyclotron Facility, its operational history and condition at the time of survey when conducted between June 2010 and April 2011. It also provides radiological characterization data for the basement of an interconnecting building, Building 49 "Materials and Structures Building".

Data were collected from Buildings 140 and 49, land area directly above Building 140 and south of Building 49, and selected background reference areas. In general, seven types of radiological data were to be collected: (1) gamma walkover surveys of land areas to direct judgmental sampling based on gamma radiation levels; (2) beta and gamma exposure rate measurements within buildings to evaluate external radiation exposure; (3) beta and alpha scan and static measurements of structures to evaluate total surface contamination; (4) systematic and judgmental soil samples of land areas to evaluate concentrations of radioactive materials in soil; (5) sump samples to evaluate potential groundwater contamination; (6) concrete samples to evaluate surface and subsurface volumetric contamination; and (7) smear samples of building surfaces and equipment to evaluate loose-surface contamination. In addition, a hazardous materials survey was conducted to assess the presence of asbestos, lead-based paint (LBP), mercury contamination, polychlorinated biphenyls (PCB), and other regulated materials located in Building 140.

Site characterization results for each building or area are summarized below. More specific information can be found in Sections 7.0 through 17.0 of this report.

1.1 Cyclotron Facility (Building 140)

Cyclotron Vault (Room 002)

Volumetric radiological contamination was identified at depth in Vault concrete walls, floor, and ceiling. Eu-152 was identified in almost all analyses performed and it is the predominant radionuclide with a maximum activity of 4.97 pCi/g. The Eu-152 activity appears to peak at a depth of approximately 4-inches in Vault concrete. Other radionuclides identified include Co-60, Eu-154, and Na-22, but at much lower concentrations than Eu-152.

Several small areas of elevated activity were identified on the floor and pipe trench during collection of beta scan measurements. However, most surfaces surveyed did not exceed the scan investigation level. The maximum activity (118,000 dpm/100 cm^2) was found on a steel floor plate next to the particle accelerator. No alpha was detected during collection of scan and static measurements.

Loose-surface contamination was only identified at 4 discrete locations. Smear results identified Co-60 as the radionuclide of concern at very low concentrations.

A total of 10 metal samples were collected from various equipment/components located within the Vault. Co-60 was identified in all analyses performed. Other radionuclides identified include Na-22, Al-26, Ag-108m, Sb-125, Eu-154, Ni-63, H-3, and Sr-90.

A maximum gamma dose rate of 8 mrem/hr contact and 1 mrem/hr at 1-foot was observed on a beam stop valve located near the southeast corner of the room. No beta radiation was detected. General area dose rates were collected throughout the room ranged from 0.013 to 0.15 mrem/hr.

Shield Room & Vault Entrance (Room 002)

No elevated beta or alpha activity was identified during collection of scan and static measurements. The average total surface beta measurements ranged from 244.8 ± 99.4 to 707.4 ± 169.8 dpm/100 cm^2 (one standard deviation). No alpha was detected above the instrument static MDC. These results are indistinguishable from measurements collected in the selected background reference area (basement of Building 100).

No loose surface contamination was found. All smear results were <MDA for both beta and alpha. The smears were composited and analyzed by gamma spectroscopy and no gamma activity was detected.

A water and sediment sample was collected from the Shield Room and Vault Entrance sumps. No Cyclotron related radionuclides were identified in any sample. However, Cs-137 was identified in the Vault Entrance sump sediment at 0.18 ± 0.07 pCi/g. This result had a relatively high uncertainty and it is likely a false positive.

No sources of radiation were identified within the Shield Room or Vault Entrance. General area gamma dose rates ranged from 0.006 to 0.01 mrem/hr.

Skylight Room (Room 005), Pump Pit, Building 49 to 140 Corridor, & Storeroom

Scan measurements identified two small areas of elevated beta activity located on the Building 49 to 140 Corridor floor. A maximum activity of 17,700 dpm/100 cm^2 was found near the north end of the Corridor. Positive alpha (186 dpm/100 cm^2) was also found near the south end. All other surfaces surveyed did not exceed the scan investigation level. No elevated beta or alpha activity was identified in the Skylight Room, Pump Pit, and Storeroom.

No loose surface contamination was identified. All smear results were <MDA for both beta and alpha. The smears were composited and analyzed by gamma spectroscopy and no gamma activity was detected.

A concrete core sample was collected in the Skylight Room and at one of the elevated activity areas identified on the floor in the Building 49 to 140 Corridor. A water and sediment sample was collected from the Pump Pit sump. No Cyclotron related radionuclides were identified in any sample when gamma spectroscopy analysis was performed.

No sources of radiation were identified in any area. General area gamma dose rates ranged from 0.004 to 0.007 mrem/hr. These dose rate results are indistinguishable from measurements collected in the selected background reference area (basement of Building 100).

Hot Storage Room (Room 004)

Several small areas of elevated beta activity were identified inside the storage caves and on the wall outside the caves. The beta activity ranged from 5,500 to 64,217 dpm/100 cm^2. Alpha was also detected with a maximum activity of 7,590 dpm/100 cm^2.

Loose surface contamination was found on two smears with a maximum of 4,759 dpm/100 cm^2 beta and 3,427 dpm/100 cm^2 alpha. The smear with the highest activity was analyzed by a vendor laboratory for a full range of radionuclides. Ra-226, Sr-90, and Tc-99 were identified.

No sources of radiation were identified in any area. General area gamma dose rates ranged from 0.008 to 0.009 mrem/hr. Contact gamma dose rates were collected on beam tube components located near the center of the room. All contact dose rates were <0.1 mrem/hr.

Neutron Therapy Room (Room 001)

Beta and alpha scan measurements identified no elevated activity above the scan investigation level. The mean beta static measurement activity ranged from 0.1 ± 165 to 458 ± 266 dpm/100 cm^2 (one standard deviation). The maximum beta activity was 958 dpm/100 cm^2. The maximum alpha activity was 55 dpm/100 cm^2. These results are indistinguishable from measurements collected in the selected background reference area (basement of Building 100).

No loose surface contamination was identified. All smear results were <MDA for both beta and alpha. The smears were composited and analyzed by gamma spectroscopy and no gamma activity was detected.

One concrete core sample was collected on the floor under the vertical collimator. No Cyclotron related radionuclides were identified when gamma spectroscopy analysis was performed.

General area gamma dose rates in walkways throughout the room ranged from 0.008 to 0.12 mrem/hr. A radioactive source locker and pallet of resistors were two sources of radiation found in the room. Contact gamma dose rates ranged from 0.32 to 1.8 mrem/hr contact.

Neutron Therapy Control Room (Room 006), Corridor, & Outer Stairway

Beta and alpha scan measurements identified no elevated activity above the scan investigation level. The mean beta static measurement activity ranged from 64.1 ± 105 to 457.1 ± 202 dpm/100 cm^2 (one standard deviation). The maximum beta activity was 764 dpm/100 cm^2. The maximum alpha activity was 40 dpm/100 cm^2. These results are indistinguishable from measurements collected in the selected background reference area (basement of Building 100).

No loose surface contamination was found. All smear results were <MDA for both beta and alpha. The smears were composited and analyzed by gamma spectroscopy and no gamma activity was detected.

No sources of radiation were identified in any area. General area gamma dose rates ranged from 0.007 to 0.013 mrem/hr.

Mechanical Equipment Room & Driveway

Beta and alpha scan measurements identified no elevated activity above the scan investigation level. The mean beta static measurement activity ranged from 507.2 ± 161 to 854.6 ± 197 dpm/100 cm^2 (one standard deviation). The maximum beta activity detected was 1120 dpm/100 cm^2. The maximum alpha activity detected was 41 dpm/100 cm^2. These results are indistinguishable from measurements collected in the selected background reference area (basement of Building 100).

No loose surface contamination was identified. All smear results were <MDA for both beta and alpha. The smears were composited and analyzed by gamma spectroscopy and no gamma activity was detected.

One concrete core sample was collected on the floor next to the vertical collimator beam tube. No Cyclotron related radionuclides were identified in any sample when gamma spectroscopy was performed.

Embedded Piping

Beta and alpha scan and static measurements were collected at the openings of all piping systems. No activity was observed above background.

Smear samples were collected from the various piping systems surveyed. All smear results were <MDA for both beta and alpha. The smears were composited and analyzed by gamma spectroscopy and no gamma activity was detected.

A total of 5 sediment samples and 1 metal sample were collected and analyzed. No Cyclotron related radionuclides were identified in any sample when gamma spectroscopy was performed.

1.2 Basement of the Materials and Structures Building (Building 49)

Beta and alpha scan measurements identified no elevated activity above the scan investigation level. The mean beta static measurement activity ranged from 10.7 ± 120 to 413 ± 201 dpm/100 cm^2 (one standard deviation). The maximum beta activity was 834 dpm/100 cm^2. No alpha was detected above the instrument static MDC. These results are indistinguishable from measurements collected in the selected background reference area (basement of Building 100).

No loose surface contamination was found. All smear results were <MDA for both beta and alpha. The smears were composited and analyzed by gamma spectroscopy and no gamma activity was detected.

General area gamma dose rates ranged from 0.007 to 0.023 mrem/hr. A box containing old smoke detectors was found in the Health Physics Office with a contact dose rate of 2.2 mrem/hr.

1.3 Land Areas

A total of 30 systematic surface soil samples and 2 split samples were collected from 30 locations within the land area directly above the Cyclotron Facility (Building 140). No subsurface samples were collected. All samples were analyzed by gamma spectroscopy. In addition, 1 sample was sent to a vendor laboratory for gamma spectroscopy and hard-to-detect (HTD) radionuclide analyses. Based on the soil sample results, radionuclide concentrations representative of normal background were found in all samples.

In addition to sampling, a direct gamma walkover survey was performed over 100% of the Building 140 land area. No elevated activity was identified during the gamma survey; therefore, no additional soil samples were collected.

1.4 Hazardous Materials Survey

A Hazardous Materials Survey was also conducted during the survey to assess the presence of asbestos containing material (ACM), lead-based paint (LBP), mercury contamination, polychlorinated biphenyls (PCB), and other regulated materials located in Building 140. The survey included a building inspection, sampling of suspected hazardous materials, followed by a documented inventory of the locations and quantities of hazardous materials.

Laboratory analysis confirmed that seven materials located in Building 140 contained asbestos. The materials included pipe insulation, floor tile and associated mastic, vibration dampener, fire door, and a piping gasket.

116 areas of painted components of different color, substrate and component were identified. Lead was found in all painted components except for the brown door casings.

Mercury testing was performed underneath thermostats and in low lying areas including floor drains, sump pits, floor trenches, etc. Mercury vapor concentrations were not measured above the 0.005 milligrams per cubic meter (mg/m^3) limit provided in Chapter 6 of the GRC Occupational Health Programs Manual [NASA 2012].

A total of nine PCB wipe samples were collected in suspect areas of Building 140. Four of the nine areas reported levels of PCBs; however, all samples were below 50 parts per million (PPM).

Various other regulated building materials were identified during the survey including fluorescent light bulbs and ballasts, hazardous exit signs, thermostats, smoke detectors, containers and pumps containing oil, acetone and other chemicals, beryllium targets, lead bricks, sheets and shield pigs, pumps contaminated with mercury oil, emergency lights, and air conditioning units.

1.5 Summary of Radionuclides Identified in Samples

Table 1-1 provides a list of radionuclides identified in samples collected in Building 140. These radionuclides should be considered during decommissioning activities, including waste transportation and disposal, dose modeling, and development of derived concentration guideline levels (DCGLs).

Table 1-1, Building 140 Radionuclides of Interest

Sample Matrix	Radionuclides Identified	Suspected Method of Production
Building Concrete	Co-60 Eu-152 Eu-154 Na-22	Accelerator produced activation of structural materials
Smears (Loose-Surface Contamination)	Co-60 Cs-137 Na-22 Ra-226 Sr-90 Tc-99	Accelerator produced activation products and byproduct materials from Cyclotron operations. The Tc-99 contamination most likely resulted from a radioactive spill that occurred in 1969 and discussed in the Characterization Plan [NASA 2010]. [1]
Metals (Cyclotron Components)	Ag-108m Al-26 Co-60 Eu-154 H-3 Na-22 Ni-63 Sb-125 Sr-90	Accelerator produced activation products and byproduct materials from Cyclotron operations.
Sediment (Sumps & Pipe Trenches)	Co-60 Cs-137	The Co-60 activity is a result of byproduct materials from Cyclotron operations. Cs-137 was identified in the Vault Entrance sump at 0.18 pCi/g. Cs-137 is not a Cyclotron radionuclide of concern and its presence at very low levels is consistent with that found in fallout in soils from former nuclear weapons testing. The Cs-137 activity was most likely tracked into the building from soil located outside the facility.
Water (Sumps)	None	N/A
Soil	Cs-137	Activities are consistent with normal Cs-137 background levels in soil. This activity is most likely not a result of Cyclotron operations.

[1] A significant contamination event occurred in June 1969. A target of Tc-99 (t ½ of 213,000 years) from Case Western Reserve University was received for irradiation and was intended to be returned to the University after irradiation. A seal leaked on the material causing a spread of radioactive material. A dozen people were found to have clothing contamination and rooms H-5, H-6, the hallway between H-6 and C-4, Rooms C-2, C-4, C-5, and the beam room were contaminated in Building 140. In addition, the hallways in the basement leading to the cyclotron area from Room 6, Rooms H-1, H-7, H-9, and the rooms 121 and 122 were also contaminated. All areas were decontaminated by wiping down the contaminated surfaces.

1.6 Future Characterization Activities

The characterization data provided in this report may be insufficient for determining the extent of conditions in some areas of Building 140. Additional data should be collected during decommissioning to verify radionuclide distributions and the extent of contamination that may be present. Future sampling that may be needed during decontamination and decommissioning (D&D) are provided below.

- Subsurface Soil - No subsurface soil samples were collected during this characterization study as the initial plan was to totally remove all Building 140 structures and to characterize subsurface soil during building excavation and demo. If the end condition of building reuse is selected, subsurface sampling should be performed to include soils immediately above and surrounding the vault, including soils below the cyclotron machine.

- Cyclotron Vault - If a building reuse scenario is selected, additional concrete samples should be collected in areas directly below the cyclotron machine and main components following removal. In-situ beta/gamma radiation measurements should be performed prior to sampling. Biased samples should be collected at highest activity locations.

  Core samples should be collected in walls to determine the full depth of activated concrete as technicians were not able to successfully drill past the rebar matting and other obstructions within walls.

  Direct beta and alpha measurements should be collected on upper walls, ceilings, and pipe trench as limited radiological data was collected during this study as a result of interferences or oils on surfaces within the trench.

- Neutron Therapy Control Room and Shield Room - Direct beta and alpha measurements should be collected in these rooms as limited radiological data was obtained during this study.

- Hot Storage Room and Building 49 to 140 Corridor - Alpha surface contamination was identified inside and near the Hot Caves and on the floor in the Corridor. Remediation support surveys should also include alpha measurements to verify that the contamination was successfully remediated.

- Skylight Room Pump Pit - Additional measurements/samples should be collected in this area as the sump system was active and inaccessible for surveying.

- All Areas - Direct beta and alpha measurements and smears should be collected in all locations during interference removal.

- Mechanical Equipment Room Roof - Roofing materials most likely contain asbestos. Samples were not collected during this study as damage would have been caused by sampling. Samples should be collected prior to building demolition.

2.0 INTRODUCTION

This report presents the results of the site characterization survey of the Cyclotron Facility located in Building 140 and potentially impacted rooms and hallways of the basement of an interconnecting building, Materials and Structures Building (Building 49). In addition, it provides survey results for land areas directly above Building 140 and results of a hazardous materials survey conducted for Building 140. Background reference area results are also included for comparison with measurements performed in areas potentially impacted by Cyclotron Facility operations.

All site characterization survey data were collected in accordance with instructions provided in the NASA GRC document titled "Characterization Plan for the GRC Cyclotron Facility, Revision 0" [NASA 2010].[2] Science Applications International Corporation (SAIC) performed the site characterization survey for NASA under NASA/GSA Blanket Purchase Agreement Number NNC08BA02B, Base Task 300, Release Order 300.23, Modification 1. SAIC's subcontractor, TTL Associates, Inc. out of Toledo, Ohio performed a hazardous materials survey in accordance with the Sampling and Analysis Plan (SAP) included in Attachment 9.

The radiological aspect of the characterization survey included an assessment of the cyclotron machine, control and beam management components, support systems, Building 140 structure, and land area directly above and surrounding Building 140. In addition, it included some rooms and hallways located in the basement of Building 49, which could have been impacted by cyclotron related operations and research. The primary objectives of the characterization survey as described in the Characterization Plan [NASA 2010] included the following:

- Determine the nature and extent of radiological and industrial contaminants.
- Provide radiological data to support classification of the facility (MARSSIM impacted Class 1, 2, or 3 or non-impacted).
- Provide data to support evaluation of remedial alternatives and technologies.
- Support development of the Decommissioning Plan and Final Status Survey Plan.
- Provide input to pathway analysis/dose or risk assessment models for determining site-specific derived concentration guideline levels (DCGLs).
- Provide input for estimating health and safety and environmental impacts as a result of decommissioning activities.
- Provide data for preparing project schedules, cost estimates, and waste estimates.
- Provide data to support development of waste stream profiles to meet disposal facility waste acceptance criteria.
- Provide data needed to complete Final Status Survey (FSS) Design Packages.

[2] The Characterization Plan for the GRC Cyclotron Facility consists of a main body and a series of appendices. The appendices include the specific number of samples and measurements to be collected, their locations, and instructions for collection and analysis of data. This information was incorporated into survey packages to provide specific instructions to survey team members for collection of data.

This report provides the necessary information to satisfy the primary objectives outlined above. The data collected included beta and alpha direct scan and static measurements, loose-surface alpha and beta contamination surveys, beta/gamma contact and general area dose rate measurements, and volumetric samples (i.e., concrete, water, soil, and sediment). Laboratory analyses were performed to identify the radionuclides involved and their concentrations. In addition, this report provides results of the hazardous materials survey conducted to identify industrial contaminants located in Building 140.

Section 3.0 of this report provides a description of the site. This includes the Building 140 layout, its relation to other buildings and facilities, design and materials of construction, building contents and use, systems and services, building modifications, and final configuration for site characterization. Facility photos are included in Attachment 1.

Section 4.0 provides information on the general history of the Cyclotron Facility gathered through review of records associated with the operation and maintenance of the facility and interviews performed with present and former employees.

Section 5.0 provides a general discussion of the survey design and implementation process and methodologies applied during collection of site characterization data. It also includes descriptions of the written NASA procedures and Survey Request packages developed and used to implement and control site characterization activities.

Section 6.0 provides a description of the radiological instrumentation used during site characterization, including discussions on instrument calibration, performance checks, and measurement sensitivity.

Sections 7.0 through 17.0 provide summaries of radiological survey results for Buildings 49 and 140, land area above Building 140, and selected background reference areas.

Section 18.0 provides a summary of quality assurance and quality control (QA/QC) information that was applied during site characterization.

Section 19.0 presents a description of the hazardous materials survey performed to identify and quantify the various industrial contaminants found at the facility.

Section 20.0 includes a list of references used to support the text.

Supporting information (i.e., photographs, data tables, Hazardous Materials Survey Report, etc.) is provided in Section 21.0, "Attachments".

3.0 SITE DESCRIPTION

The Cyclotron Facility is located at the NASA Glenn Research Center at Lewis Field in Cleveland, Ohio. The facility is located in Building 140 which interconnects at the basement level with Building 49. The two buildings lay between Wolcott Road and the northwestern edge of the Cleveland Hopkins International Airport boundary fence near the southeastern boundary of NASA property.

3.1 Building 140

The Cyclotron Facility is located in Building 140, which is predominantly a below-grade structure (see Figure 3-1). The above grade structures include the Mechanical Equipment Room (MER), also referred to as the Magnet House, an outer stairway, and the Skylight Room removable roof cover (see Figure 3-2). The building is normally accessed via a connecting corridor from the basement at the southeast corner of Building 49, but may also be accessed directly through an outer stairway to the southeast.

The 69-inch cyclotron particle accelerator is housed within the Cyclotron Vault (Room 002) along with other support equipment and components including beam tubes, an overhead 10-ton crane, electrical panels, pumps, motors, cable trays, and an upgraded electrical heating system. Large equipment can be moved in or out of the vault through a set of water-tight doors, which are situated next to the personnel access door. A services trench runs from the vault to the north to Building 49. Refer to photos in Attachment 1, Figures 19 through 26.

The Neutron Therapy Room (NTR), Room 001, also referred to as the Treatment Room, is located south of the Cyclotron Vault. In 1975, a cooperative program between NASA and the Cleveland Clinic Foundation was implemented in which the cyclotron would be operated by NASA technicians to provide neutron radiation therapy to oncology patients under the care of Cleveland Clinic Foundation medical staff. Building remodeling was done to provide for a patient receiving area. Additional particle beam control systems were installed to allow generation of collimated neutron beams in the NTR. Two beam tubes run through the south wall of the Cyclotron Vault into the NTR. One of the beam tubes penetrates through the ceiling and runs to the Mechanical Equipment Room. Refer to photos in Attachment 1, Figures 15 through 18.

The Skylight Room (SLR), Room 005, is located directly east of the Cyclotron Vault. The Skylight Room houses the main circuit breakers for Buildings 49 and 140, various cable trays, an overhead hoist, building ductwork, a stainless steel sink, and a building sump system. A large movable shield is located next to the water-tight doors on the west side of the room. This shield was once used to shield radiation streaming through the personnel access doors during cyclotron operation. A removable roof cover is located in the ceiling near the center of the Skylight Room. The cover can be removed to allow large equipment to be moved into and out of the building. Refer to photos in Attachment 1, Figures 1 through 8.

The Hot Storage Room (HSR) is located southeast of the Skylight Room and houses twelve (12) hot caves and a section of beam tube. The Hot Storage Room was once used to store high radiation target materials. It should be noted that the hot cave shield doors were disassembled by

NASA, radiologically surveyed to "no detectable" levels, and removed from the building prior to start of site characterization. Refer to photos in Attachment 1, Figures 9 through 12.

The NTR Control Room, also referred to as the Therapy Control Room, is located south of the Skylight Room and was used as a sample counting room and to monitor neutron therapy. The room is generally free of cyclotron equipment except for a sump, cabinets, and a heating system. A connecting stairway leads outdoors to ground level at the southeast corner of the building. Refer to photos in Attachment 1, Figures 13, 14, and 34.

The Building 140 exterior is constructed primarily of reinforced concrete. Mechanical Equipment Room (MER) walls are constructed of a cinder block interior and brick exterior. A concrete walkway with retaining walls leads to a garage door entrance on the west side of the MER. The subsurface section of the outer stairway consists of concrete with tin siding in the above grade entranceway. Interior walls surrounding the Cyclotron Vault consist of concrete. Sheet rock and cinder block was used in interior walls in the NTR Control Room and hallway.

An earthen mound covers the Cyclotron Vault and served as radiation shielding during cyclotron operation (see Figure 3-2). The land area surrounding the underground building is protected by a fence and serves as a barrier to prevent unauthorized personnel from accessing the facility. Refer to photos in Attachment 1, Figures 27-30.

3.2 Building 49

Building 49 consists of a basement level, two levels above grade, and two small penthouse areas. The basement includes support offices and a radiochemistry laboratory, which is currently active and used to support current cyclotron activities. Normal access to the Cyclotron Facility is via a connecting corridor from the basement at the southeast corner of Building 49.

The building has been subjected to several modification projects since its original construction and its layout today differs considerably from its layout at the time the cyclotron was in operation. It presently houses the Materials and Structures Building. A layout diagram showing the basement area of Building 49 is shown in Figure 3-3. Layouts for the remaining floors are not shown as they were not impacted by Cyclotron Facility operations.

Figure 3-1, Cyclotron Facility – Building 140 Basement

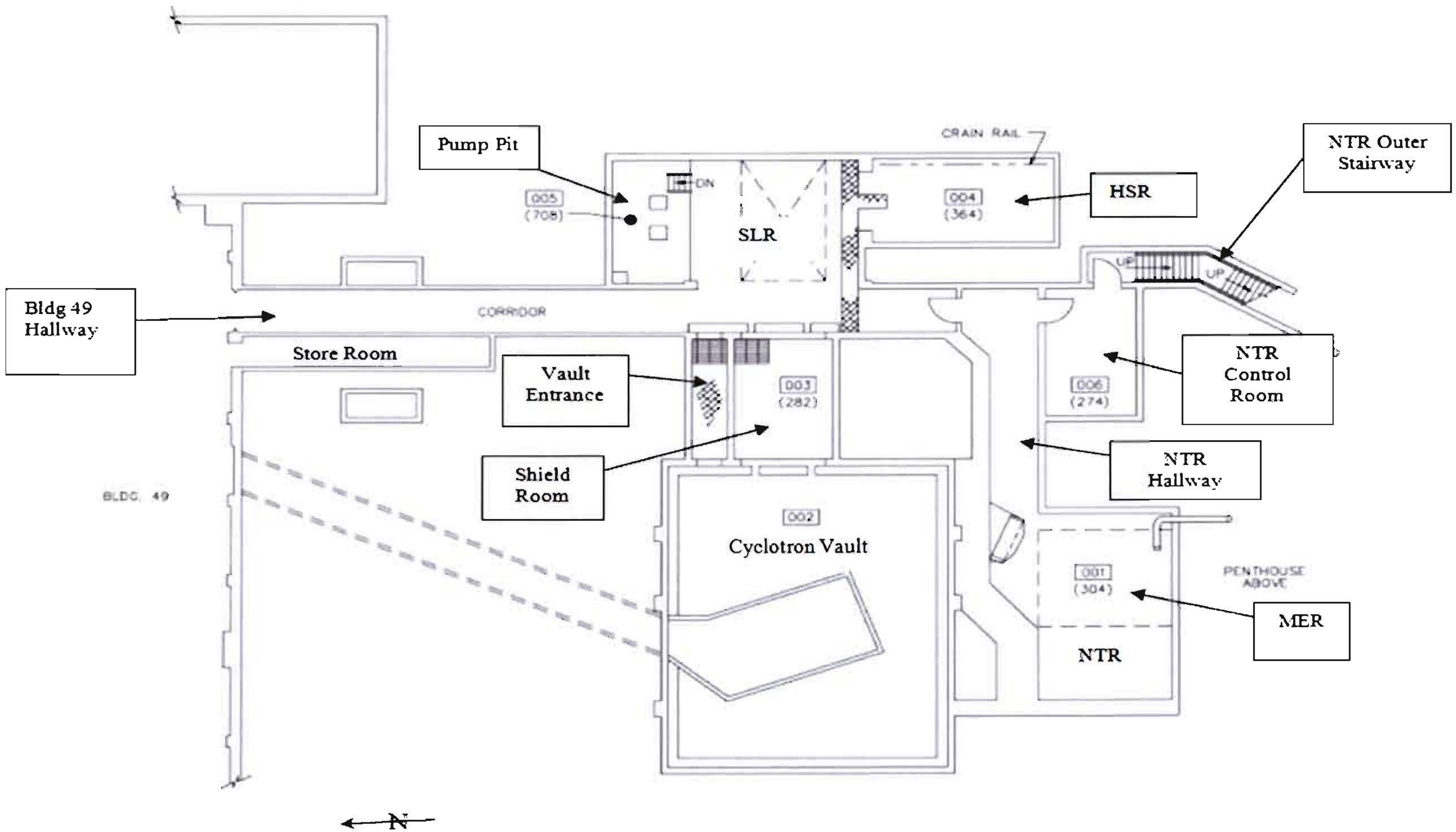

Figure 3-1 Notes:

1. Room numbers are depicted by the numbers (e.g., 002) inside the small rectangles.
2. NTR = Neutron Therapy Room, SLR = Skylight Room, MER = Mechanical Equipment Room, HSR = Hot Storage Room

Figure 3-2, Cyclotron Facility (Building 140) Magnet House & Above Grade Property

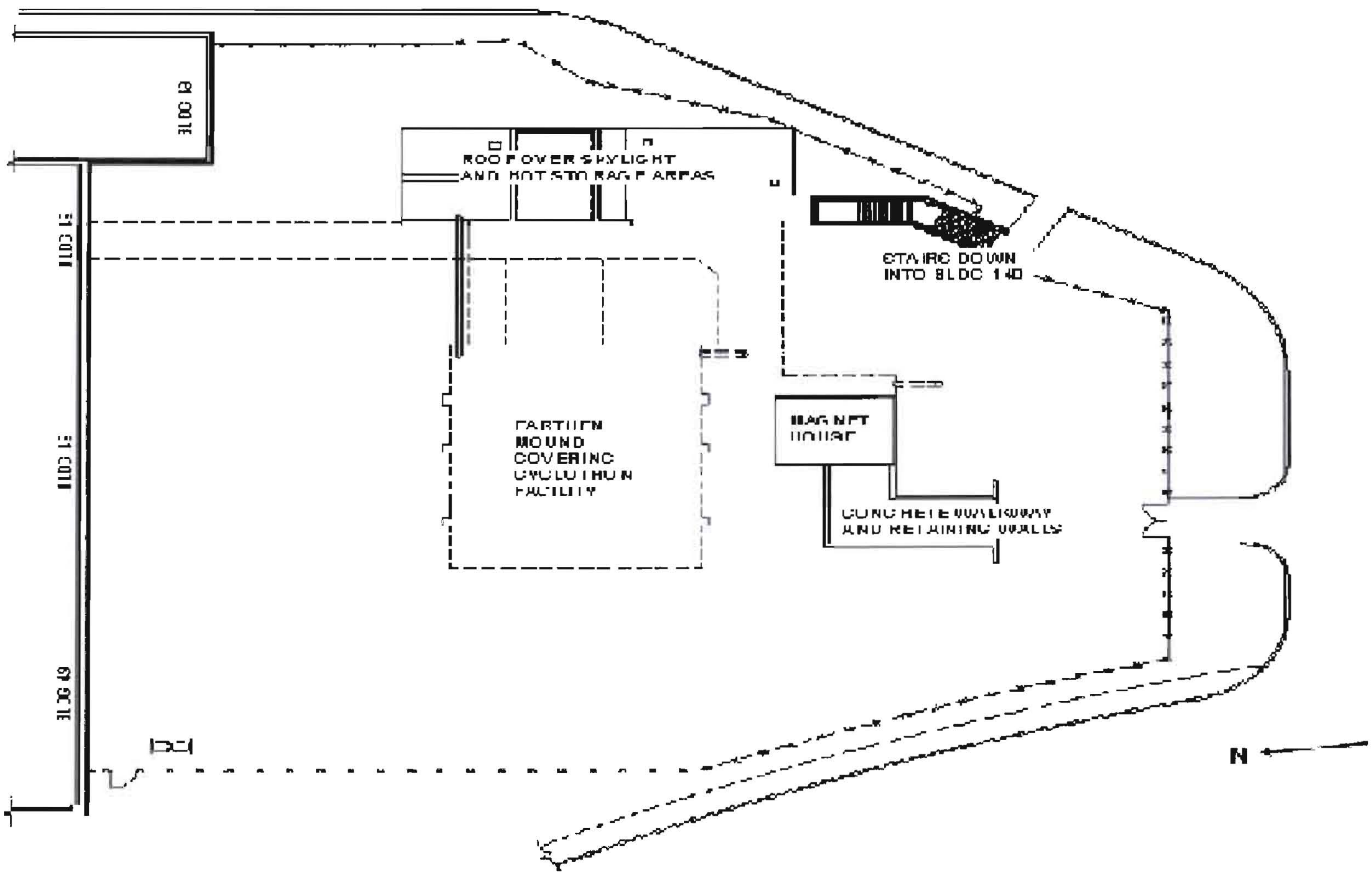

Figure 3-3, Basement of the Materials and Structures Building (Building 49)

4.0 CYCLOTRON FACILITY HISTORY

This section provides information on the general history of the Cyclotron Facility.[3] It was collected during development of the Historical Site Assessment through review of logs and records pertaining to the operation and maintenance of the facility and interviews with present and former employees.

4.1 Origins

The NASA Glenn Research Center facilities have their origin in 1941 when construction began on the National Advisory Committee for Aeronautics (NACA) Aircraft Engine Research Laboratory near Cleveland, Ohio. Construction was on a 351 acre site of land acquired from the City of Cleveland at the South West boundary of the city. In May of 1942, research began at the facility. The facility was designed to focus on research and development of aircraft engines and would eventually play a major role in the advances in aircraft propulsion during World War II. In 1947, the facility was renamed the Flight Propulsion Research Laboratory. The following year it was renamed the Lewis Flight Propulsion Laboratory in honor of George W. Lewis under whose leadership the early site had been developed and managed. In 1958, President Eisenhower announced the formation of a new space agency, the National Aeronautics and Space Administration (NASA), formed around the organization of NACA, and renamed the facility the NASA Lewis Research Center. In 1998 the facility was renamed NASA John H. Glenn Research Center at Lewis Field.

In 1946 the Army Air Force initiated the Nuclear Energy for Propulsion of Aircraft (NEPA) program. Although the facility had expressed an interest in being actively involved in the NEPA program, its research role involved mostly theoretical thermal hydraulic research in support of the program. The primary role of the GRC remained aircraft engine research and development.

In the late 1940's, General Electric began construction of the Cyclotron Facility under a 'turn-key' agreement with NACA. In 1955, after about seven years of construction, the 60-inch cyclotron became operational and was turned over to NACA for performance of materials research. It was used in performing material irradiation studies. The system was a charged particle accelerator capable of accelerating alpha particles (He-4 nuclei), protons, and deuterons to energies of 40 MeV, 20 MeV, and 20 MeV respectively. The system operated extensively until 1970 when it was shutdown to perform a significant upgrade to the machine. Dismantlement of the old cyclotron equipment was performed from October of 1970 until July of 1971 when installation of the modified equipment began. Work continued on the upgrade installation until January of 1973 when startup testing began. The modified system was a 69-inch cyclotron with the capability of variable energy. It was a more versatile system capable of accelerating protons to energies of 10 to 55 MeV, alpha particles to energies of 24 to 58 MeV, deuterons to energies of 7 to 29 MeV, and He-4 nuclei to energies of 15 to 65 MeV. In addition, the system could produce collimated neutron beams by bombardment of beryllium target materials. The modified machine had a much higher efficiency, meaning that less particle impingement would occur inside the machine, resulting in less radioactive activation of the

[3] Information included in this section was obtained from Revision 0 of the "Characterization Plan for the GRC Cyclotron Facility" [NASA 2010].

materials of construction. Following the upgrade, the facility continued to operate until it was permanently shut down in December 1990.

4.2 Chronology

A chronology of major milestones is provided below. A more comprehensive discussion of Cyclotron Facility operations and post-shutdown activities is included in Section 4.3 below. Emphasis is on operations with radioactive materials that could affect the facility conditions.

- Late 1940s – General Electric began construction of the 60-inch cyclotron.
- 1955 – Cyclotron operations began after seven years of construction.
- 1955 through 1970 – Cyclotron was used extensively for material irradiation studies, general nuclear physics research, and some production of radioisotopes by bombardment of targets.
- October 1970 through July 1971 – Significant upgrade to the cyclotron was performed. The 60-inch cyclotron was disassembled and replaced by a more efficient 69-inch cyclotron. Testing and research resumed following the upgrade.
- 1975 – Facility modifications were performed to prepare for treatment of Cleveland Clinic oncology patients through neutron radiation therapy.
- 1975 through 1990 – Cyclotron operations continued. A majority of the run time was dedicated to treatment of oncology patients. However, records indicate some production of radioisotopes occurred for medical administration to human patients.
- December 1990 – Cyclotron operations were terminated.
- 1991 – Facility decontamination plan was implemented, which included removal of unnecessary equipment/materials, general decontamination of laboratories and impacted rooms located in Buildings 49 and 140, and closure of the cyclotron for decay-in-storage.

4.3 History of Operations

The cyclotron operated extensively from 1955 to 1970 performing a variety of irradiation experiments. The activities included radiation damage studies, general nuclear physics research, and some production of radioisotopes by bombardment of targets. The research was done in support of NACA and NASA efforts to study basic nuclear phenomenon and later to study the effects of radiation on materials in support of aircraft nuclear propulsion. As the nation began exploration of high altitude flight and ultimately space research, the studies and research were to advance our knowledge of the behavior of materials when exposed to ionizing radiation. Although the review of historical documents showed very little documentation of the cyclotron being used as an isotope production facility, there was evidence in the operating log entries to indicate that a significant amount of target bombardment was performed with the intention of producing radioisotopes that were sent to other facilities for additional experimentation. Following the system upgrades from 1970 to 1971, the nuclear research continued at a greater pace. These later operating phases included experiments and production runs that involved neutron production using high energy particle impingement on target materials.

A number of log entries during this time indicate that targets were irradiated for other customer laboratories that included other NASA research centers, some private sector facilities, and several university laboratories. A number of historical records imply that nuclear related research at the cyclotron was terminated in 1972 a few months after the upgraded cyclotron became operational. However, logs and other operating records show that irradiation experiments continued until permanent shut down of the system.

In 1975, a cooperative program between NASA and the Cleveland Clinic Foundation was implemented in which the cyclotron would be operated by NASA technicians to provide neutron radiation therapy to oncology patients under the care of Cleveland Clinic Foundation medical staff. Building remodeling was done to provide for a patient receiving area. Additional particle beam control systems were installed to allow generation of collimated neutron beams in a patient treatment center. The center was part of a national research program that included Fermi Laboratory, Naval Research Lab, Texas A&M, and the University of Washington. The NASA system was the first to include both horizontal and vertical neutron beam capabilities. The experimental treatment program lasted until late 1990 when the program was terminated after treating about 1200 patients.

Operator log entries for the period 1975 through 1990 indicate that the majority of the cyclotron run time was devoted to the Cleveland Clinic Foundation treatment studies. However, irradiation experiments also continued at the cyclotron for other NASA irradiation studies and support of university programs. There was documentation in the records that would indicate that the cyclotron was also engaged in the production of radioisotopes prepared for medical administration to human patients in hospitals in the area.

Throughout the operational period, the cyclotron operation was carefully controlled by written procedures and policies and a written safety manual. The operations were subjected to extensive review and oversight by the GRC's Radiation Safety Committee comprised of senior management personnel with extensive technical expertise in the areas of health physics and radiation protection. The same health physics technical staff that performed radiation monitoring and safety activities throughout the GRC also provided monitoring and radiation protection activities at the cyclotron.

In 1991, NASA implemented a plan that would perform decontamination and release of the cyclotron facility. The plan included decontamination of laboratories and rooms in Building 49, decontamination of adjacent rooms in Building 140 and converting them to use by the Health Physics Staff, and closure of the cyclotron itself for decay-in-storage. In 1994, NASA planned a major renovation to Building 49 to establish the Comparative Technology Research Center. The decontamination plan included 15 rooms in Building 49.

In Building 49, the following areas were included in the plan:

- Rooms 8, 9, 10, 12, 13, 14, 15, 16, 17, 20, 21, 22, and 23

- The laundry room
- The mop closet

In Building 140, the following were included:

- Cyclotron Vault
- Neutron Therapy Room
- Neutron Therapy Control Room
- Hot Storage Area
- Skylight Room

The following activities were performed as part of the decontamination:

- Radiological surveys were performed,
- Unnecessary oils and chemicals were removed,
- Unused materials and equipment were removed,
- The ventilation stack from hot laboratory hoods in Building 49 was removed,
- Ventilation and heat was modified in the cyclotron area to better stabilize the environment for long term storage.

Radioactive contaminants identified during surveys included Cs-137, Co-60, Ra-226, Na-22, Mn-54, Ag-110, Th-232, and U-238. It was also expected that the concrete walls of the facility may contain the activation products Eu-152 and Eu-154.

During operation, radiation from the cyclotron vault was shielded by a 'water wall' and water filled door. The water wall held about 3000 cubic feet of water and the door held about 100 cubic feet of water. Both were drained during the decontamination project. Analysis of water samples from the two tanks found no radioactive contamination. There was no record of any surveys of the internal surfaces of the tanks.

Oil contaminated with Zn-65, an activation product of irradiated copper, was packaged in drums and allowed to decay. After a period of decay of about six years, it was disposed of as waste oil.

Decontamination was performed under the supervision and oversight of radiation protection personnel. It involved wiping of surfaces, brushing and sanding to abrade surfaces where needed, and by hand washing with soap and water. When water was used, it was carefully contained in pails that were then placed in the cyclotron vault to evaporate. The contaminated pails were then disposed of as dry active waste. This was done to avoid any potential contamination of drainage systems that could have occurred if the waste water had been disposed of by pouring down the drains. Nearly all of the loose radioactive material in the facility was packaged and shipped for disposal as radioactive waste.

When the project completed in late 1994, Building 140 was left secured to allow further decay of the cyclotron and the beam equipment. Affected areas of Building 49 were decontaminated and released for unrestricted use before beginning the Building 49 renovation project. The release criteria applied was:

- Removable Contamination:
  - Alpha — 20 dpm/100 cm^2
  - Beta-Gamma — 400 dpm/100 cm^2
- Fixed Contamination
  - Alpha — 2X Background Levels
  - Beta-Gamma — 2X Background Levels

Although the source of these criteria was not clearly cited in the documentation, the removable contamination criteria are within the criteria specified in NRC Regulatory Guide 1.86 [NRC 1974]. In addition, based on expected background levels in the areas, the fixed contamination limits would also be within 1.86 criteria.

The cyclotron machine itself was considered too highly contaminated with activation products to proceed with dismantlement at the time. The magnet coils and other beam control components were supplied with a source of de-ionized water for cooling. Records indicate that complete drainage of the cooling system could not be confirmed at the time. It was drained to the extent practical by opening the accessible petcocks.

During storage, the cyclotron area was subjected to frequent radiological monitoring and physical inspection. Maintenance has been performed to assure the continuation of reasonably good ventilation and heat in the area.