Final Survey Report
NASA GRC Cyclotron Facility
Cleveland, Ohio
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Enclosure

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LIST OF ACRONYMS & SYMBOLS

AL	Action Level
α	Alpha
β	Beta
cc	Cubic Centimeter
cm	Centimeters
cm^2	Square Centimeters
Co	Cobalt
dpm	Disintegrations per Minute
DCGL	Derived Concentration Guideline Limit
DQO	Data Quality Objective
Eu	Europium
FSS	Final Status Survey
γ	Gamma
GRC	Glenn Research Center
He	Helium
hr	Hour
HSR	Hot Storage Room
m	Meter
MARSSIM	Multi-Agency Radiation Survey & Site Investigation Manual
MDA/MDC	Minimum Detectable Activity/Concentration
MER	Mechanical Equipment Room
MeV	Mega Electron-Volts
mg/m^3	Milligram per Cubic Meter
mrem	Millirem
NACA	National Advisory Committee for Aeronautics
NaI	Sodium Iodide
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NTR	Neutron Therapy Room
pCi/g	Picocuries per Gram
QA	Quality Assurance
QC	Quality Control
SLR	Skylight Room
SR	Survey Request
TEDE	Total Effective Dose Equivalent
µrem	Microrem
VSP	Visual Survey Plan®

1.0 EXECUTIVE SUMMARY

This report presents results of the Final Status Survey (FSS) of the National Aeronautics and Space Administration (NASA) Cyclotron Facility, also known as Building 140, located at the John H. Glenn Research Center (GRC), Lewis Field, in Cleveland, Ohio. This report describes the Cyclotron Facility, its operational history, previous characterization results, and condition at the time of survey when conducted between January 2017 and April 2017.

For the purpose of the FSS, the Cyclotron Facility was split into two separate functional areas: the "Cyclotron Vault," which housed the cyclotron particle accelerator, and "Building 140 Auxiliary Rooms," which denotes all other areas of the facility. The Cyclotron Vault and much of its contents were determined to have measurable levels of radioactive activation products (principally Co-60 and Eu-152) as a result of cyclotron operation. Consequently, the cyclotron yoke pieces, windings, cores and all of the cyclotron-associated equipment, magnets, beam tubes, electrical systems, vacuum equipment, cooling equipment, and other interferences were removed and disposed as radioactive waste prior to performing FSS. Since no other areas outside of the Cyclotron Vault were found to be volumetrically contaminated, two separate methodologies were used to determine if Building 140 could be released from all radiological controls and removed from the NASA Radioactive Materials License. First, the Cyclotron Vault was dose modeled using data collected during the site characterization study [SAIC 2012] along with new survey and sample results obtained after all remedial actions were complete to determine if it met the criteria of 10CFR20, Subpart E, Section 20.1402, Radiological Criteria for Unrestricted Use [NRC 2015]. Second, with no evidence of appreciable volumetric contamination being found outside of the Cyclotron Vault during characterization activities, these remaining areas, denoted as Building 140 Auxiliary Rooms, were surveyed and released from radiological controls in accordance with NASA Glenn Research Center Occupational Health Programs Manual – Chapter 8 [NASA 2014] and current radioactive material license conditions.

1.1 Cyclotron Vault and Beam Tubes

Final Status surveys of the Cyclotron Vault were conducted from March 3 to March 8, 2017. Final status surveys consisted of scan surveys, total direct surveys, dose rate measurements, and removable contamination measurements. These final status surveys were designed using the guidance provided in the Multi- Agency Radiation Survey and Site Investigation Manual (MARSSIM) [NRC-2000] to demonstrate compliance with the release criteria for unrestricted use specified in 10 CFR 20.1402.

The Cyclotron Vault was divided into two survey units. MARSSIM Class 1 survey unit comprising the floor and lower walls up to 6 feet and a Class 2 survey unit comprising the upper walls and ceiling. 100% of the Class 1 survey unit and 50% of the Class 2 survey unit were direct scan surveyed for beta activity. A total of 49 systematic fixed point beta measurements were taken. A 100 cm^2 smear sample was taken at each fixed point location and analyzed for removable alpha, beta, and tritium activity. Gamma scans were performed on 100% of the Class 1 survey unit and 50% of the Class 2 survey unit. A total of 49 systematic fixed point and 15 background reference area dose rate and one-minute static measurements were taken. Gamma scans and one-minute static measurements were taken on the internal surfaces of each beam tube and beam dump.

This report presents sufficient data to support the conclusion that the facility meets the release criteria. Final status surveys demonstrate that building structures affected by the operation of the cyclotron meet the release criteria and are suitable for unrestricted release. Based on the building occupancy scenario, the Total Effective Dose Equivalent (TEDE) to an average member of the critical group is less than 5.6 millirem/year (mrem/yr), approximately 22% of the release criterion of 25 mrem/yr.

Additionally, for building structures with potential volumetric activation products, including beam tubes, a site-specific dose model was developed and the scenario analyses of NUREG 1640 Volume 1 “Radiological Assessments for Clearance of Equipment and Materials from Nuclear Facilities,” were used to develop an upper bound of potential doses from plausible future “alternate scenarios.” These alternate scenario analyses for recycling, renovation, and disposal demonstrate that potential doses are much less than 1 mrem/yr to the maximally exposed individuals [NRC 2003].

1.2 Building 140 Auxiliary Rooms

Building 140 Auxiliary Rooms encompass those areas outside of the Cyclotron Vault where no volumetric contamination as a result of cyclotron operations was found. Based upon historical information on these areas as well as previous characterization results, this area was divided into fifteen survey units comprising 100% of the floor areas and lower walls up to 6 feet. A total of 7,207 ft^2 was direct surveyed for total beta activity and 2,708 ft^2 were direct surveyed for both alpha and beta activity. A total of 173 systematic fixed point alpha and beta measurements were taken. A 100 cm^2 smear sample was taken at each fixed point location and analyzed for removable alpha and beta activity. No activity was found at any location above the release limits specified in NASA Glenn Research Center Occupational Health Programs Manual – Chapter 8 [NASA 2014] after all remedial actions were completed.

1.3 Land Areas

A total of 30 systematic surface soil samples were collected from 30 locations within the land area directly above the Cyclotron Facility (Building 140). All samples were analyzed by gamma spectroscopy. No cyclotron related activity was found at any location. In addition to sampling, a direct gamma walkover survey was performed over 100% of the Building 140 open land area. No elevated activity was identified during the gamma survey. Therefore, no additional soil samples were collected [SAIC 2012].

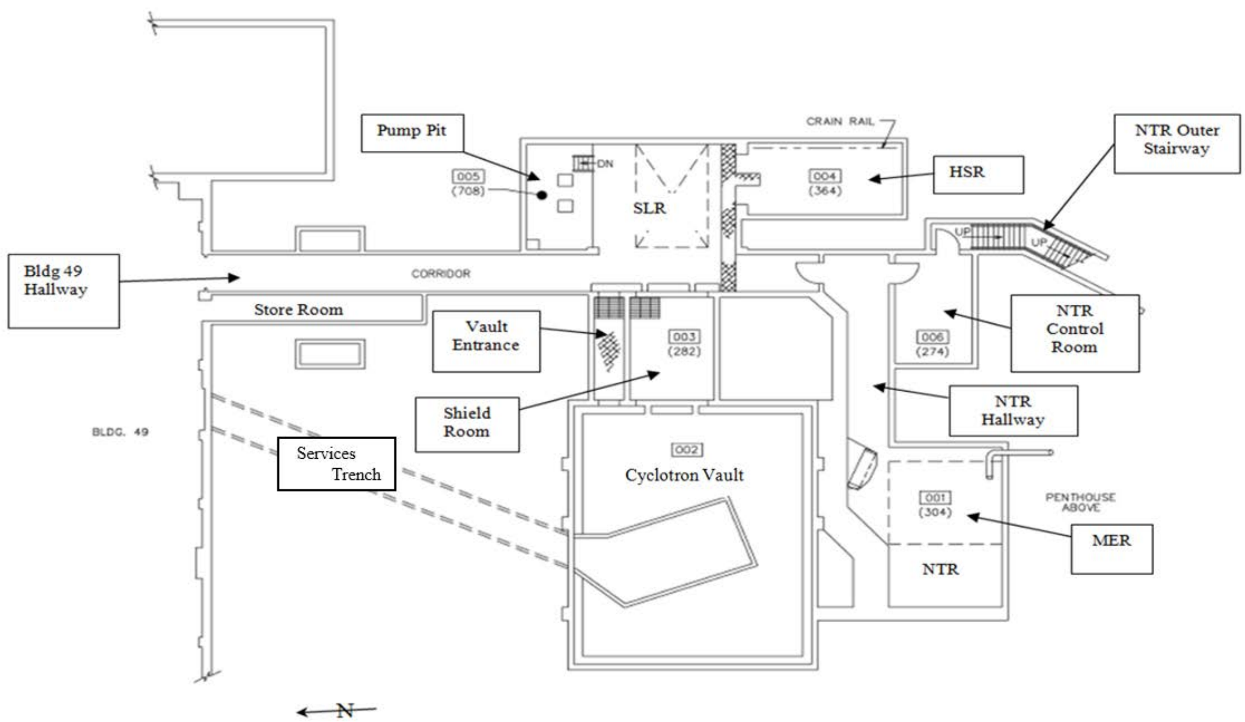
In 2015, 76 core samples of the overburden soils immediately adjacent to the Vault structure were collected from 9 subsurface locations immediately above the Vault roof and 8 subsurface locations adjacent to the Vault exterior walls from the top of the structure to the footers. All samples were analyzed by gamma spectroscopy. Eu-152 activity was found at one location along the west wall between the 18’ and 24’ depth level with the highest activity observed being 0.93±0.25 pCi/g. This activity is 11% of the NRC default soil screening value for Eu-152 given in NUREG 5512, Volume 3, Table 6.91 [NRC 1999]. Based upon the limited extent of observed activation as well as this low concentration measured, the level of Eu-152 in the subsurface soil is not significant. No cyclotron related activity was found at any other location.

2.0 SITE DESCRIPTION

The Cyclotron Facility is located at the NASA Glenn Research Center's Lewis Field site in Cleveland, Ohio. The facility comprises the entirety of 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.

The cyclotron particle accelerator is located in Building 140, which is predominantly a below-grade structure (see Figure 2-1). The above grade structures include the Mechanical Equipment Room (MER), also referred to as the Magnet House, and the Skylight Room (SLR) removable roof cover. 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.

Figure 2-1, Cyclotron Facility – Building 140 Basement



The 69-inch cyclotron particle accelerator was 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 other support systems. Large equipment can be moved in or out of the vault via the Shield Room through a set of water-tight doors, which are situated next to the personnel access door. A services trench ran from the Cyclotron Vault to Building 49.

The Neutron Therapy Room (NTR), Room 001, also referred to as the Target Room or Beam Room, is located south of the Cyclotron Vault. Initially, accelerated particles could be directed in beam tubes through the six-foot thick southern Vault wall to the NTR to conduct various experiments. 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 ran through the south wall of the Cyclotron Vault into the NTR. One of the beam tubes penetrated through the ceiling and into the MER where a steering magnet directed the beam into a vertical neutron delivery system. The second beam tube directed the beam to a horizontal neutron delivery system.

The Skylight Room (SLR), Room 005, is located directly east of the Cyclotron Vault. The SLR housed electrical switchgear, various cable trays, an overhead hoist, building ductwork, stainless steel sink, a pumping system to empty the Shield Water and Personnel Access Rooms, and a building sump system. A removable roof cover is located in the ceiling near the center of the SLR. The cover can be removed to allow large equipment to be moved into and out of the building.

The Hot Storage Room (HSR) is located southeast of the SLR and housed twelve (12) shielded caves used to store high radiation target materials. A beam delivery system was also installed to deliver accelerated particles to a scattering chamber in the HSR.

The NTR Control Room, also referred to as the Low Level Counting Room, is located south of the SLR and was used to monitor and control neutron therapy operations and as a sample counting room. A connecting stairway leads outdoors to ground level at the southeast corner of the building.

The Building 140 exterior is constructed primarily of reinforced concrete. 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.

An earthen mound covers the Cyclotron Vault and served as radiation shielding during cyclotron operation. The land area surrounding the underground building is protected by a fence and served as a barrier to prevent unauthorized personnel from accessing the facility during particle accelerator operations.

3.0 CYCLOTRON FACILITY HISTORY

This section provides information on the general history of the Cyclotron Facility[1] 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.

3.1 NASA GRC 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

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

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

3.2 Cyclotron Facility Chronology

The following is a chronology of major milestones of the Cyclotron Facility operations and post-shutdown activities. Emphasis is on operations with radioactive materials that could affect the facility conditions.

- 1948 – 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 through 1994 – 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. Subsequently, affected areas of Building 49 were renovated to include the present configuration.
- 2010 – 2011 – Facility Characterization plan was implemented and completed.
- 2013 through 2016 – Interference removal activities and additional characterization were conducted in preparation for the decommissioning of the Cyclotron and Building 140.
- 2017 – The Cyclotron was disassembled and removed as low level radioactive waste. The FSS of the Cyclotron Vault and the remainder of Building 140 was performed.

4.0 FINAL SURVEY DESIGN & IMPLEMENTATION

Building 140 was divided into two distinct areas for the FSS of the Cyclotron Facility. The Cyclotron Vault, which is known to contain residual volumetric contamination as a result of neutron activation of structural materials, and the remaining areas of the building, which are denoted herein as the Building 140 Auxiliary Rooms. The FSS of the Cyclotron Vault was performed in accordance with NASA GRC Cyclotron Decommissioning Project Work Execution Package WEP-16-002, Revision 1, *Building 140 Radiological Survey* by Chase Environmental Group, Inc. (Attachment 1). The FSS of the remainder of Building 140 surface areas were surveyed in accordance with Cyclotron Final Status Survey Design #1 by Leidos Health Physics staff (Attachment 2).

4.1 Cyclotron Vault

Final status surveys were performed to demonstrate that residual radioactivity in each survey unit satisfied the predetermined criteria for release for unrestricted use. The final status survey was conducted using the Data Quality Objective (DQO) process. Characterization and remedial action survey data was used as final status survey data to the extent possible. Final status surveys consisted of scan surveys, total direct surveys, dose rate measurements and removable contamination measurements. All survey data was documented on survey maps and associated data information sheets. The use of reference background areas or paired background comparisons is not necessary for beta surface contamination measurements. The background rate for NaI and MicroRem detectors was determined in an area non-impacted for activation, and of similar construction in the corridor north and east of the cyclotron vault. Background was subtracted from survey unit measurements and used to calculate actual MDCs for measurements.

4.1.1 Determining Compliance for Surface Activity

For Class 1 areas, if it is determined that all total activity results are less than the applicable derived concentration guideline level (DCGL), then the survey unit passes and no further statistical tests are required. If the average of the total activity results is above the $DCGL_W$, the survey unit fails. If any total activity measurement is greater than the $DCGL_W$, and the average is less than the $DCGL_W$, the Sign Test is performed. A summary of the Sign Test statistical tests is provided in Table 4-1 below.

Table 4-1: Sign Test Summary of Statistical Tests

Survey Result	Conclusion
All measurements less than the DCGL	Survey unit meets release criterion
Average greater than DCGL	Survey unit does not meet release criterion
Any measurement greater than DCGL and the average less than DCGL	Conduct Sign Test

For Class 2 areas, data results are initially compared to the investigation levels. These investigation levels are provided to help ensure that survey units have been properly classified. If all data results in Class 2 areas are less than the investigation levels, then the survey unit is determined to meet the release criterion. If these investigation levels are exceeded, then an investigation is performed to verify the initial assumptions for classification and determine the appropriate resolution (e.g., additional scans or survey unit reclassification).

Removable contamination measurements will be compared directly to the applicable removable DCGL. No contingency is established for elevated removable contamination. Therefore, if any removable contamination is detected which exceeds the removable contamination limit, the survey unit is determined not to meet the release criterion. However, if all removable contamination measurements are less than the removable contamination limit, then compliance shall be determined based on total activity measurements.

4.1.2 Determining Compliance for Volumetric Activity

For volumetric activity, the Wilcoxon Rank Sum (WRS) test is used to evaluate external dose rate measurements. If the highest result of any location inside the cyclotron room is less than $DCGL_w$ above the lowest result of any location from the background reference area, then the survey unit passes and Wilcoxon Rank Sum (WRS) test is not required. If the survey unit average dose rate is more than the $DCGL_w$ above the background reference area average dose rate, then the survey unit fails. If the survey unit average dose rate is less than the $DCGL_w$ above the background reference area average dose rate, then the WRS Test will be performed. A summary of the WRS statistical tests is provided in Table 4-2.

Table 4-2: WRS Summary of Statistical Tests

Survey Result	Conclusion
Difference between largest survey unit measurement and smallest reference area measurement is less than DCGL	Survey unit meets release criterion
Difference of survey unit average and reference area average is greater than DCGL	Survey unit does not meet release criterion
Difference between any survey unit measurement and any reference area measurement greater than DCGL and the difference of survey unit average and reference area average is less than DCGL	Conduct WRS test

Removable contamination measurements will be compared directly to the applicable removable DCGL. No contingency is established for elevated removable contamination. Therefore, if any removable contamination is detected which exceeds the removable contamination limit, the survey unit is determined not to meet the release criterion. However, if all removable contamination measurements are less than the removable contamination limit, then compliance shall be determined based on dose rate measurements.

4.1.3 Embedded Pipes (Beam Tubes and Beam Dumps)

Beam tube internals are not subject to occupancy scenarios and are outside the scope of MARSSIM; therefore, gamma scans and static measurements of the internal surfaces of beam tubes and beam dumps were performed to estimate their activity concentrations and allow them to be modeled for recycling and re-use scenario dose assessments. The internal surface of each beam line was scanned starting at the opening closest to the vault and scanning outward from the vault. Beam tubes were scanned using a 2” x 2” NaI detector to estimate the Co-60 activity concentration in the beam tubes at maximum rate of 1” per second with the detector centered in the beam tube. At specific locations within the tube, a one-minute static measurement was obtained for dose modeling calculations.

4.2 Building 140 Auxiliary Rooms

Various areas of the building outside the Cyclotron Vault were used to handle, store, and process radioactive materials. In addition, neutron therapy operations conducted in the NTR resulted in residual activation of portions of the beam tubes that extended into the NTR. The beam tubes and associated beam dumps were assessed for residual radioactivity separately from the building surfaces as described in Section 4.1.3. Characterization data of the remaining materials and structures found in Building 140 Auxiliary Rooms indicates that volumetric activation was not a concern. Final status surveys were conducted by performing required scan surveys, total activity direct surveys, and removable contamination measurements to demonstrate that residual radioactivity in each survey unit satisfied the criteria for release for unrestricted use. A Survey Request (SR) was developed to direct instrument selection and use, sample collection, survey documentation, and Quality Control requirements specified in the survey design.

4.2.1 Data Quality Objectives

This section outlines the approach and identifies the key parameters for the survey design following the MARSSIM framework for applying the DQO process [NRC 2000].

4.2.2 Problem Statement

In order to release these areas from radiological control without restriction, one must determine if they meet the surface release criteria for unrestricted use.

4.2.3 Principal Decisions

Determine if the materials and structures of Building 140 Auxiliary Rooms meet the release criteria as stated in the NASA Glenn Research Center Occupational Health Programs Manual – Chapter 8 [NASA 2014].

4.2.4 Decision Inputs

100% of all survey units were scanned for beta activity and three survey units where alpha activity was found during characterization were also scanned for alpha activity. One minute static beta or alpha/beta measurements were obtained at any location where scans exceeded the action level (AL) set at 50% of the surface release criteria.

One minute static alpha and beta measurements were systematically located with a random starting location in most survey units. Static measurements were randomly located in small or oddly shaped survey units. Visual Sample Plan® (VSP) software was used to determine the number and location of static measurements in each survey unit. Decision error probabilities were set at $\alpha = 0.05$ (Type I error) and $\beta = 0.10$ (Type II error).

Removable contamination levels were assessed by obtaining a 100 cm^2 smear sample at each static measurement location. The Tennelec Series 5 XLB counting system was used to analyze all smear samples for alpha and beta gross activity.

4.2.5 Study Boundaries

This survey design covered the interior surfaces of Building 140 excluding the Cyclotron Vault. These areas were assessed separately due to the presence of volumetrically contaminated building materials. Embedded pipes, beam tubes, and other inaccessible surfaces were also assessed separately. Other items within each survey unit (e.g., electrical panels, fixtures, etc.) were judgmentally surveyed as directed by the FSS Manager. Characterization results indicated that there was no reasonable potential to expect that Building 140 upper walls and ceilings would be impacted by licensed cyclotron activities [SAIC 2012]. Therefore, these surfaces were not subject to additional survey unless FSS surveys of adjacent areas indicated a potential for residual contamination. A complete list of survey units is provided below.

Table 4-3: Building 140 Survey Units

Title
Survey Unit 3 – Skylight Room Floor
Survey Unit 4 – Skylight Room Lower Walls
Survey Unit 5 – Skylight Room Pump Pit
Survey Unit 6 – Building 49 to 140 Floor and Lower Walls
Survey Unit 10 – Hot Storage Room Floor
Survey Unit 11 – Hot Storage Room Lower Walls
Survey Unit 13 – Neutron Therapy Beam Room Floor
Survey Unit 14 – Neutron Therapy Beam Room Lower
Survey Unit 17 – Neutron Therapy Hallway Floor
Survey Unit 18 – Neutron Therapy Hallway Lower Walls
Survey Unit 19 – Neutron Therapy Control Room Floor
Survey Unit 22 – HSR 6”x20” Caves
Survey Unit 23 – HSR 12”x12” Caves
Survey Unit 24 – Building 49 Room 10A Sump Pit Floor
Survey Unit 25 – Magnet House Floor & Lower Walls

4.2.6 Decision Rule

The maximum permissible fixed and removable alpha and beta contamination levels are provided in the NASA Glenn Research Center Occupational Health Programs Manual – Chapter 8 [NASA 2014] shown below.

Table 4-4: Release Criteria

NUCLIDE[a]	TOTAL		REMOVABLE[b e] (dpm/100 cm²)
	AVERAGEb c (dpm/100 cm²)	MAXIMUMb d (dpm/100 cm²)	
U-natural, U-235, U-238, and associated decay products	5,000 α (alpha)	15,000 α	1,000 α
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5,000 dpm β-γ (beta-gamma)	15,000 dpm β-γ	1,000 dpm β-γ

[a] Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should be applied independently.
[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector by background, efficiency, and geometric factors associated with the instrumentation.
[c] Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such objects.
[d] The maximum contamination level applies to an area of not more than 100 cm^2.
[e] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of know efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

If the activity at each fixed point measurement location within each survey unit, including any investigation measurements is below the building surface release criteria for fixed and removable alpha and beta activity, the survey unit will pass.

5.0 SURVEY RESULTS - CYCLOTRON VAULT

The cyclotron and all associated components, systems, and equipment were removed from the facility. All the data contained in this report demonstrates that the facility meets release criterion for unrestricted use. Structural surfaces and system removable activities were below the established DCGL of 150 dpm/100 cm^2. In the same manner, total activities present on structural surfaces were found to yield annual doses to a member of the critical group in the order of 1.9 mrem/yr (<8% of the release criterion of 25 mrem/yr established in 10 CFR 20.1402). The average measured background was 5.0 μrem/hr. The average dose rate within the cyclotron vault was 6.6 μrem/hr. Assuming an occupancy of 2,340 hr/yr, the total effective dose equivalent to an average member of the critical group was calculated to be 3.7 mrem/yr (<15% of the release criterion of 25 mrem/yr established in 10 CFR 20.1402). Alternate scenario analyses using NUREG 1640 (with results less than 1 mrem/yr per scenario) demonstrate that the occupancy scenario is the limiting scenario. Even under the assumptions of the conservative analysis performed, an upper bound of potential doses to an average member of the critical group is less than 5.6 mrem/yr. Based solely on potential dose averted, further action is not consistent with the ALARA principle. ALARA is further supported by the occupational risks associated with removal, movement, packaging, transport, processing and disposal along with the risks associated with the restoration of remediated areas for future use of the space. The complete Cyclotron Vault FSS Report is contained in Attachment 3.

6.0 SURVEY RESULTS – BUILDING 140 AUXILIARY ROOMS

A total of 173 systematic static fixed point survey locations were obtained over 15 survey units. All survey units were scanned 100% for beta activity and 3 survey units were also scanned 100% for alpha activity. A total of 34 biased Investigation Measurement (IM) data points were collected in survey units where elevated activity was detected during scanning. These areas were remediated and the survey reperformed. A smear sample was collected at each fixed point survey location, including IMs and analyzed for alpha and beta activity. The final residual total and removable radioactivity in each survey unit is significantly below the Release Criteria shown in Table 4-4. A total of 561 ft^2 (6%) was rescanned and 15 (10%) static measurements were reperformed with a different equivalent instrument and technician for Quality Control purposes. All QC measurements resulted in the same conclusion as the original survey results. A summary of final surface activity results is presented in Table 6-1. See Attachment 4 for the complete release record for each Survey Unit.

Table 6-1: Building 140 Surface Activity Results

Room – Survey Unit	Average Fixed Activity ($dpm/100cm^2$)		Maximum Fixed Activity ($dpm/100cm^2$)		Removable Activity [1] ($dpm/100cm^2$)	
	Alpha	Beta	Alpha	Beta	Alpha	Beta
Skylight Room Floor - SU 3	18	420	43	567	<MDA	<MDA
Skylight Room Lower Walls - SU 4	15	120	38	360	<MDA	<MDA
Skylight Room Pump Pit - SU 5	17	685	33	891	<MDA	<MDA
Building 49 to 140 Corridor Floor and Lower Walls - SU 6	5	362	37	1037	<MDA	<MDA
Hot Storage Room Floor - SU 10	15	657	36	1193	<MDA	<MDA
Hot Storage Room Lower Walls - SU 11	27	404	47	1200	<MDA	<MDA
Neutron Therapy Beam Room Floor - SU13	4	245	19	440	<MDA	<MDA
Neutron Therapy Beam Room Lower Walls - SU 14	13	317	21	558	<MDA	<MDA
Neutron Therapy Hallway Floor - SU 17	23	256	43	400	<MDA	<MDA
Neutron Therapy Hallway Lower Walls - SU 18	28	322	44	433	<MDA	<MDA

Room – Survey Unit	Average Fixed Activity (dpm/100cm²)		Maximum Fixed Activity (dpm/100cm²)		Removable Activity [1] (dpm/100cm²)	
	Alpha	Beta	Alpha	Beta	Alpha	Beta
Neutron Therapy Control Room Floor - SU 19	18	110	36	347	<MDA	<MDA
HSR 6"x20" Caves - SU 22	9	7	17	160	<MDA	<MDA
HSR 12"x12" Caves - SU 23	-2	-53	10	87	<MDA	<MDA
Building 49 Room 10A Sump Pit Floor - SU 24	6	211	16	353	<MDA	<MDA
Magnet House Floor & Lower Walls - SU 25	-8	619	16	1163	<MDA	<MDA

[1] The α/β MDA for Tennelec System 1 is 13.3/21.9 respectively. For Tennelec System 3 the α/β MDA is 13.5/19.8.

7.0 CONCLUSIONS

The results presented above demonstrate that NASA GRC's Building 140 Cyclotron Facility satisfies the release criteria in 10CFR20 Subpart E. The principal conclusions are:

- Scan surveys were performed in all survey units with scan coverage equal to or greater than the percentage requirements for the survey unit classification.
- All total surface activity measurements are all less than the applicable release limits. Removable activity was less than 10% of the total activity.
- The potential dose in the Vault to an average member of the critical group is less than 5.6 mrem/yr from all sources including embedded piping.
- All soil sample radionuclide activity concentrations are below their respective NRC default screening values.
- All survey unit mean fixed measurement results are below the $DCGL_W$ or surface release criteria for unrestricted use, hence no statistical tests were required.
- Residual surface activity met the criteria for unrestricted release and soil concentration measurement results are shown to be less than NRC screening level values - demonstrating that the ALARA criterion is satisfied. ALARA is further supported by the occupational risks associated with removal, movement, packaging, transport, processing and disposal along with the risks associated with the restoration of remediated areas for future use of the space.

8.0 REFERENCES

NASA 2010 Safety and Mission Assurance Directorate, NASA Glenn Research Center, *Characterization Plan for the GRC Cyclotron Facility*, Rev. 0.

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NRC 2003 NUREG 1640, Volumes 1 & 2, *Radiological Assessments for Clearance of Equipment and Materials from Nuclear Facilities*, June 2003.

NRC 2015 10CFR20, *Standards for Protection against Radiation, Subpart E*, December 2015.

SAIC 2012 NASA GRC Cyclotron Facility *Site Characterization Report*, Cleveland, Ohio, November 2012.

9.0 ATTACHMENTS

Attachment 1 – Decommissioning Project Work Execution Package WEP-16-002, Revision 1, *Building 140 Radiological Survey Only*

Attachment 2 – Cyclotron Final Status Survey Design #1

Attachment 3 – Chase Environmental Cyclotron Vault Final Status Survey Report

Attachment 4 – Survey Unit Release Records for Building 140 Auxiliary Rooms