

Enclosure

**OAK RIDGE ASSOCIATED UNIVERSITIES:
SITE STATUS REPORT FOR AIR ZOO AEROSPACE & SCIENCE MUSEUM IN PORTAGE,
MICHIGAN**

[INSERT DATE AFTER SIGNATURE]

EXECUTIVE SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) requested that Oak Ridge Associated Universities (ORAU) perform a radiation survey of the Air Zoo Aerospace and Science Museum (Air Zoo) located at 6151 Portage Road (Main Campus) and 3101 East Milham Road (East Campus) in Portage, Michigan. State of Michigan representatives identified Air Zoo as a potential site with aircraft gauges and other items containing radium paint. On October 24, 2018, NRC staff made a preliminary visit to the museum, identified three areas producing gamma radiation levels above ambient background levels and confirmed the presence of both intact and damaged radium gauges and other items. These gauges were identified in some aircrafts on display in the museum and in storage areas. Due to these findings, NRC determined that an initial site visit should be performed at the Air Zoo properties. The objectives of this initial site visit were to locate and document the number of discreet sources of radium-226 and distributed radium-226 contamination present, to determine if there are any current health and safety concerns, and to determine if further action by NRC is needed.

ORAU performed the radiation surveys in accessible portions of the Air Zoo properties in December 2018, focusing on aircraft with radium gauges and on storage areas. Several planes, two of which are accessible to museum patrons, were identified as containing radium gauges and other items containing radium. Patrons are not expected to spend more than 15 minutes within these cockpits and estimated doses are low based on occupancy. Similarly, stored radium-containing items are kept well away from regular work areas and are inaccessible to museum patrons. The inspection team estimates that, in combination, there are more than 100 discrete sources of radium (in the form of intact gauges, gauge parts, and other items), though a specific total could not be determined—many of the stored items were wrapped in paper or foil. Title 10 of the Code of Federal Regulations (CFR) Section 31.12 provides for a general license when 1 to 100 discrete sources of radium are present; 10 CFR 30.3 would be the applicable regulation, requiring a specific license, if more than 100 discrete sources of radium are possessed. After the conclusion of the initial site visit, Air Zoo officials informed the NRC that it does not intend to possess more than 100 items under a specific license but intends to reduce the number of items to less than 100 in accordance with a general license.

SITE STATUS REPORT

Property: Air Zoo Aerospace & Science Museum
6151 Portage Road/3101 East Milham Road
Portage, MI 49002

Docket Number: 03039139

Current Property Name(s): Air Zoo Aerospace & Science Museum

Current Property Owner(s): Air Zoo Aerospace & Science Museum

Inspection Dates: December 4–5, 2018

Inspector(s): Mike Kunowski and Bill Lin/U.S. Nuclear Regulatory
Commission (NRC), supported by Kaitlin Engel and Erika
Bailey/Oak Ridge Associated Universities (ORAU)

1.0 INTRODUCTION

The Energy Policy Act of 2005 amended section 11e.(3) of the Atomic Energy Act of 1954 to place discrete sources of radium-226 (Ra-226) under NRC regulatory authority as byproduct material. The NRC is evaluating properties where review of historical information has identified the potential use of Ra-226. Between 1995 and 2000, State of Michigan officials identified multiple switches, gauges, and other materials containing Ra-226, including localized contamination, at the Kalamazoo Aviation History Museum at 3101 East Milham Road (Michigan 1995, 1997, and 2000). A new facility at 6151 Portage Road was opened in 2011. This new facility, named the Air Zoo Aerospace & Science Museum (Air Zoo), may also contain gauges and other items containing Ra-226. NRC staff conducted a preliminary visit on October 24, 2108. During this visit, the NRC identified three areas producing radiation levels above ambient background levels and confirmed the presence of intact Ra-226 gauges and other items in some aircraft on display and the presence of both intact and damaged gauges and other items in storage areas (ORAU, 2018a, 2018b). The specific number, location, and condition of Ra-226 gauges and other items throughout the two facilities could not be fully assessed at that time, so an initial site visit with NRC and ORAU personnel was planned.

The overall objectives of the initial site visit were to locate and document the number of discreet sources of Ra-226 and distributed Ra-226 contamination present at both the East Milham Road (East Campus) and Portage Road (Main Campus) facilities, to determine if there are any current health and safety concerns, and to determine if further action by NRC is needed. Data collected from this survey will be used, if necessary, to plan future actions that may be needed to reduce Ra-226 exposure to current or future site occupants to levels that do not exceed the applicable regulatory requirements. It is important to note that destructive testing is not generally performed as described within NRC's procedures, Temporary Instruction (TI) 2800/043 *Inspection of Facilities Potentially Contaminated with Discrete Radium-226 Sources* (NRC 2018) (Agencywide Documents Access and Management System [ADAMS] Accession No. ML17297B921).

2.0 PROPERTY DESCRIPTION AND INITIAL SITE VISIT CONSIDERATIONS

2.1 Property Description and History

A couple, who began collecting World War II-era aircraft in 1959, founded the Kalamazoo Aviation History Museum, which first opened to the public in 1979. The original facility is a 4,200-m² hangar located on an over-2-hectare lot at 3101 East Milham Road. A new facility was opened in 2011 at 6151 Portage Road, and the Kalamazoo Aviation History Museum was renamed the Air Zoo. The East Milham facility was renamed the East Campus, and the Portage Road facility is the Main Campus. The Main Campus sits on an over-13-hectare lot and comprises a Main Exhibit and East Wing. The Main Exhibit floor is approximately 11,000 m² and includes a second floor mezzanine. The East Wing is approximately 3,800 m². Figure 1 is an aerial view showing the locations of East Campus (outlined in blue) and Main Campus (outlined in yellow). Figure 2 is a street view of the East Campus; Figure 3 is a close-up aerial view of the Main Campus; and Figure 4 is a street view of the Main Campus.

The Main Campus complex features interactive exhibits, aircraft and space artifacts, a theater, an archive, a library, meeting rooms, and a café (Air Zoo Brochure 2018). The Air Zoo website describes the facility as an “aerospace and science experience” that can be used for social or corporate events, featuring rare and historic aircraft, amusement park-style rides, full-motion flight simulators, a “RealD 3D/4D Missions Theater,” hands-on and interactive attractions, a playground, historical exhibits, and educational activities. Figure 5 shows the layout of the Main Exhibit floor, noting that some of the exhibits have been moved since this brochure was created. Members of the public pay to tour or rent the facility, attend summer camps, and otherwise use the facility for recreational activities. The East Campus is also open to the public [though the History section of the Air Zoo website (Air Zoo 2009) states otherwise] and contains historic aircraft and stored materials, such as gauges and switches that contain discrete sources of Ra-226. Public and employee access to discrete sources of Ra-226 is relatively limited.

Staff from the State of Michigan performed a radiation survey of the East Milham facility in October and November of 1995. Surveyors identified several aircraft instruments containing Ra-226, including one “leaking gauge,” and contamination producing maximum readings of 2,500 counts per minute (cpm) alpha, 1,500 cpm beta-gamma, and 100 picoCurie (pCi)/100 cm² of Ra-226 on the floor of a small enclosure. The floor location was decontaminated and released without restrictions in accordance with State of Michigan standards at that time. “Significant contamination” was also measured in the cockpit of the Douglas SBD-3 Dauntless, with 30,000 cpm alpha and 140,000 cpm beta-gamma on the “R/E Trim Wheels” on the left side of the cockpit (Michigan 1995) that was being refurbished by the Museum after it was retrieved from the bottom of Lake Michigan.

In 1996, the Museum requested assistance disposing of a large number of items containing Ra-226, including “materials used to clean radium from the Museum’s WW II vintage SBD Dive Bomber” (i.e., the SDB-3 Dauntless) (KAHM 1996). State of Michigan surveyors returned to the East Milham facility in January 1997 to remove gauges and other contaminated items and to resurvey the SBD. During this effort, surveyors identified a contaminated wooden box formerly used to store radium gauges and more contamination in the SBD cockpit reaching a maximum of 50,000 cpm alpha and 55,000 beta-gamma (Michigan 1997).



Figure 1. Aerial View of Air Zoo (Google Earth Pro 2017)
(Main Campus in yellow box; East Campus in blue box)



Figure 2. Street View of Air Zoo East Campus (Google Earth Pro 2017)



Figure 3. Aerial View of Air Zoo Main Campus (Google Earth Pro 2017)



Figure 4. Street View of Air Zoo Main Campus (Google Earth Pro 2017)

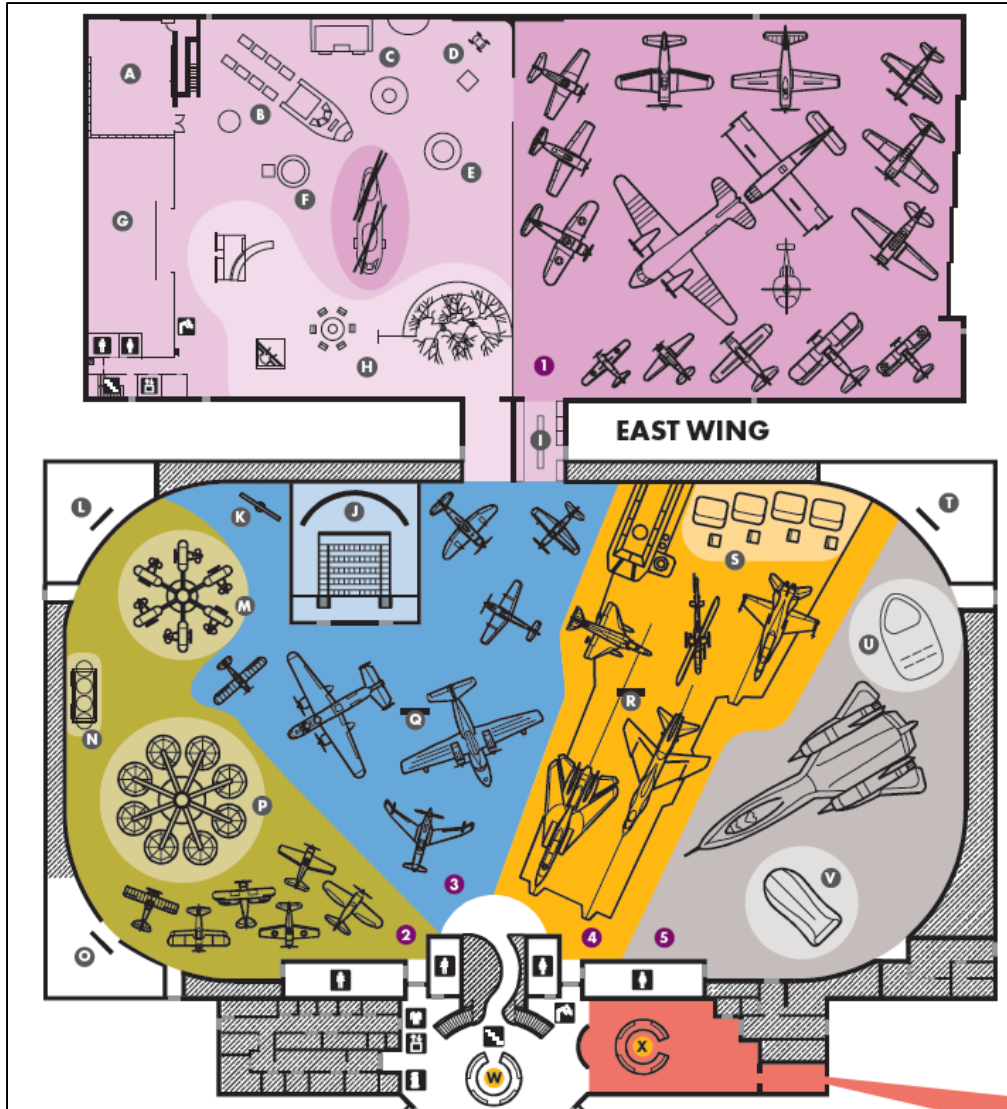


Figure 5. Layout of Main Exhibit Floor (Air Zoo Brochure 2018)

It is unclear what specific materials State personnel removed, but a 2000 memorandum from the State of Michigan to the Museum stated that “On January 14, 1997, department staff visits the Flight Center facility to remove radium gauges and other contaminated items for disposal through federal authorities.” The memorandum continues to recommend that “One large wooden box and two cement blocks were...eligible for disposal...” and that several items be removed and stored for disposal as radioactive material, including switches, lettering, and other items in the SBD cockpit. As a final note, the memorandum states that, “[t]his level of radiation does not constitute a health and safety hazard to employees as long as the radioactive material is not placed next to the body, inhaled, or ingested” (Michigan 2000).

Subsequently, the Energy Policy Act of 2005 amended 11e.(3) of the Atomic Energy Act of 1954 to give the NRC regulatory authority of discrete sources of Ra-226. Through a review of historical information, the NRC identified several sites with historic radium contamination, including Air Zoo. NRC staff performed a preliminary visit on October 24, 2018, and identified elevated radiation levels in, but not limited to: 1) World War (WW) II era planes that are

accessible to workers and members of the general public; 2) the basement storage area on the East Campus that is accessible to workers but is inaccessible to members of the general public; and 3) the archive area on the Main Campus that is accessible to workers but is inaccessible to members of the general public (ORAU 2018b). As a result of the surveys, several boxes containing Ra-226 gauges and other items were moved from more frequented work areas to locations with limited access (ORAU 2018a).

2.2 Scoping Survey Considerations

Prior to commencing initial site visit survey activities, the inspection team examined the general property layout for consistency with historical information and to identify impediments to conducting the survey as well as health and safety considerations.

3.0 SITE OBSERVATIONS AND FINDINGS

3.1 Summary of Activities

The inspection team conducted surveys at the Air Zoo properties on December 4–5, 2018. The inspection team, consisting of Mike Kunowski (December 4 only) and Bill Lin/NRC and Erika Bailey and Kaitlin Engel/ORAU, met with the State of Michigan representative, Marcus Quinlan, and site representatives, April Bryan (Exhibits and Collections Manager), Quinton Slovacek (acting as site escort), and Richard Klass (acting as site escort). The inspection team's intention was to perform radiation surveys of accessible portions of selected aircraft (due to likelihood of identifying radium), the storage area at the East Campus, and the Archive Area at the Main Campus, and to delineate discrete sources of Ra-226 from contamination, if identified.

Radiological surveys performed by the inspection team consisted of gamma radiation scans using a Ludlum model 44-10 2-inch by 2-inch (2×2) sodium iodide detector connected to a Ludlum model 2221 ratemeter/scaler and radiation exposure rate measurements using a Ludlum model 192 sodium iodide-based μ R ratemeter¹. Ludlum model 44-142 plastic scintillators connected to Ludlum model 2221 ratemeter/scalers were available for direct surface activity measurements. A hand-held identiFINDER® model R300-Z was available to confirm, if possible, the presence of Ra-226 when elevated gamma radiation levels were encountered. Table 1 presents the specific instruments used during the site visit.

Summary of Daily Activities – December 4, 2018:

The inspection team arrived at 7:00 a.m. and met with State of Michigan and Air Zoo representatives. Surveys began on the Main Campus. NRC, with input from site personnel, selected four airplanes identified in historical records as likely to contain discrete sources of Ra-226. These four airplanes were the Link Instrument Flight Trainer and nearby desk, the Curtiss-Wright XP-55 Ascender, Douglas SBD-3 Dauntless, and the Timm N2T-1 Tutor. In the afternoon, the inspection team moved to the East Campus to survey two additional airplanes: the Mikoyan-Gurevich MiG-15 and Douglas KA-3B Sky Warrior. The team concluded surveys

¹Roentgen is a unit of exposure (energy absorbed in air), whereas a rem is a unit of dose delivered to a person (resulting from the radiation energy absorbed in that person). While Roentgen and rem are related, these are different units. Because they are similar for gamma ray energies from Ra-226, NRC makes the simplifying assumption in this case that these units are equivalent (1 Roentgen = 1 rem).

for the day in the East Campus storage area. The inspection team departed the site around 5:00 p.m.

Table 1. Air Zoo Survey Instruments			
Radiation Type (units)	Detector Type	Detector Model (Number)	Ratemeter (Number)
Alpha-plus-beta (cpm)	Plastic Scintillator	44-142 (1033) Calibrated 11/28/2018	2221 (1062) Calibrated 09/11/2018
		44-142 (1032) Calibrated 11/27/2018	2221 (543) Calibrated 09/13/2018
Gross gamma (cpm)	Sodium Iodide Detector	44-10 (663) Calibrated 10/02/2018	2221 (1062) Calibrated 09/11/2018
		44-10 (907) Calibrated 09/11/2018	2221 (543) Calibrated 09/13/2018
Gross gamma (μ R/h)	Exposure Ratemeter	192 (1127) Calibrated 05/21/2018	N/A
Gamma Spectrum Analyzer (identiFINDER®)	CZT spectroscope	R300-Z (CG0343) ^a	N/A

CZT = cadmium zinc telluride

N/A = not applicable

Number = ORAU equipment barcode

cpm = counts per minute

μ R/h = microRoentgen per hour

^aA known radium source is used to confirm the identiFINDER® will identify Ra-226.

Summary of Daily Activities – December 5, 2018:

The inspection team arrived at 9:00 a.m. and spent the morning and most of the afternoon surveying the Archive Area on the Main Campus. At 5:00 p.m., the inspection team returned to the Main Exhibit area to survey and collect exposure rate measurements on two radium-bearing bombsights that were on display. The inspection team departed the site around 5:15 p.m.

3.2 Summary of Results

Appendix A presents a summary of field measurements taken during the Air Zoo initial site visit survey. Appendix B presents photographs of select items and areas associated with Table A-1 measurements. Table A-1 specifically presents smear numbers and associated measurement

results, including alpha-plus-beta measurements, gross gamma measurements (in cpm), and exposure rate measurements (in $\mu\text{R/hr}$).

Regarding smears, net (gross minus background) field counts measured using a Model 44-142 plastic scintillator are presented for all smears, and gross alpha-plus-beta results measured via liquid scintillation at a radio-analytical laboratory are also presented for select locations. The 20 locations evaluated were specifically selected to represent the highest potential for removable contamination (based on field counts) or to quantify the potential for worker or patron exposures.

The identiFinder® specifically identified Ra-226 in the Link Instrument Flight Trainer, the Curtiss-Wright XP-55 Ascender, the Timm N2T-1 Tutor, the Mikoyan-Gurevich MiG-15, the Douglas KA-3B Sky Warrior, and multiple stored items. It is noted that there were insufficient counts to identify Ra-226 in the Douglas SBD-3 Dauntless where contamination was previously identified. Additional survey details are available via the field forms, which were delivered to NRC under separate cover (ORAU 2018c).

Radiation measurement results listed in Table A-1 are dominated by the gamma component, though total “alpha-plus-beta” results are presented at non-trivial levels. Plastic scintillators respond to alpha, beta, and gamma radiation and can be misunderstood in a high gamma radiation field, such as is demonstrated here. In addition, it would be inappropriate to compare alpha-plus-beta measurement results to dose-based screening values (such as those described in *Dose Assessment Technical Basis Document for Potential Exposures to Discrete Sources of Radium-226 and Associated Contamination* [ORISE 2017]), because screening levels are derived for walls and floors of habitable structures and not individual items such as gauges or switches. Therefore, measurement data from the plastic scintillator are provided for completeness as gross and net (minus background) cpm values. The discussion presented herein focused on the gamma radiation measurements from the Exposure Ratemeter and Sodium Iodide Detector.

Exhibits and Planes. Results from the Link Instrument Flight Trainer show high contact radiation levels, reaching over 1 million gross counts (in cpm) and up to 2,000 $\mu\text{R/h}$ on contact with gauges. An individual sitting in the cockpit of the trainer would be exposed to a gamma radiation field on the order to 50-90 $\mu\text{R/h}$, depending on the specific location of the measurement. Individual gauges and switches in the Curtiss-Wright XP-55 Ascender produce similar contact results, though the combination of multiple discrete sources of Ra-226 produces a much higher exposure rate (1,400 $\mu\text{R/h}$) in the seat. The Douglas SBD-3 Dauntless has a history of contamination (as described in Michigan 1995, 1997, and 2000), but the initial site visit surveys identified only slightly elevated gamma radiation levels. It is presumed that items exhibiting elevated direct radiation levels identified in the late 1990s have been removed, but this was not specified in the State of Michigan reports. The Timm N2T-1 Tutor produced radiation levels very similar to the Flight Trainer, both on contact and at 1-m. The MiG-15 contains gauges that produce a maximum of 700 $\mu\text{R/h}$ on contact and 60 $\mu\text{R/h}$ at 1-m, similar to the Douglas KA-3B Sky Warrior, though the Sky Warrior produced only 15 $\mu\text{R/h}$ in the seat. Museum patrons are only allowed to enter the Flight Trainer and Sky Warrior cockpits, so individuals can be exposed to an average mid-torso exposure rate of approximately 70 $\mu\text{R/h}$. Museum personnel indicated that patrons typically spend up to 15 minutes in the Flight Trainer and Sky Warrior cockpits.

Storage and Archive Areas. A large number of items not installed in aircraft are stored in the East Campus storage area and Main Campus Archive Area. The inspection team estimates

that more than 100 discrete sources of radium are present. This is relevant because 10 CFR 31.12(a)(4) issues a General License when no more than 100 items (i.e., luminous products) are used or stored at the same location at any one time and 10 CFR 30.3 requires a Specific License when more than 100 discrete sources of radium are present. As shown in Appendix B, many items are stored in boxes or large plastic containers and are wrapped in foil or paper. The inspection team did not unwrap individual items due to concerns about spreading radium contamination and, therefore, could not confirm the total number of items during the initial site visit. Measurements are highlighted by a maximum static measurement of 2.6 million cpm and 4,200 $\mu\text{R}/\text{h}$ on contact for one gauge and 150 $\mu\text{R}/\text{h}$ at 1 meter from the green case shown in picture B-9, which contains multiple discrete Ra-226 sources, as shown in picture B-10. This item also produced the maximum removable result of 54.9 disintegration per minute (alpha-plus-beta), which appears trivial compared to the gamma radiation levels but suggests that Ra-226 has leaked from some items within the green case. All items are stored away from museum workers and are inaccessible to museum patrons.

3.3 Summary of Dose Assessment Results

The State of Michigan stated in 2000 that radiation levels in the East Campus, at the time, would not pose a health and safety hazard to employees as long as the radioactive material is not placed next to the body, inhaled, or ingested (Michigan 2000). The December 2018 initial site visit did not identify contamination on floors or walls (i.e., structural materials) that are traditionally associated with the need to perform dose calculations, noting that the surveys during the initial site visit focused on locating and characterizing items distributed across the two facilities. Instead, the inspection team identified individual discrete sources of radium in boxes or other containers, in airplane cockpits, or in other Air Zoo displays. Doses from gauges, switches, etc., in the Storage and Archive Areas are not presented in this assessment because those discrete sources of Ra-226 will (likely) be managed under an NRC license (specific license or general license) and do not represent uncontrolled residual activity that could expose future building occupants.

Discrete sources located in various exhibits across the museum floor do require additional consideration. The average member of the critical group at the Air Zoo site is an industrial building occupant or a museum patron, neither of which is reasonably expected to spend more than a fraction of an hour in close proximity to sources inside a cockpit or in other exhibits. As shown in Table A-1, radiation levels are dominated by the gamma pathway (i.e., removable activity is negligible), so internal pathways may be ignored. Dose is linearly proportional to exposure time, so a simple scaling calculation can be used to estimate the dose to an individual who conservatively spends up to an hour in close proximity to discrete sources of radium associated with the various aircraft on exhibit. Conservatively assuming 1 $\mu\text{R}/\text{h}$ is approximately equivalent to 1 $\mu\text{rem}/\text{h}$, and using the maximum measured exposure rate in a cockpit seat (Curtiss-Wright XP-55 Ascender):

$$\text{Dose (mrem/yr)} = 1,400 \frac{\mu\text{R}}{\text{hr}} \times \frac{1\text{hr}}{\text{yr}} \approx 1,400 \frac{\mu\text{rem}}{\text{yr}} = 1.4 \text{ mrem/yr}$$

Alternatively, it would require an individual to sit in the cockpit for 18 hours annually to receive a dose of 25 mrem/yr, though the Ascender is not accessible to the public.

Museum patrons can access the Flight Trainer and Sky Warrior cockpits, which produced a maximum exposure rate of 90 $\mu\text{R}/\text{h}$ at the seat. Again conservatively assuming a 1-h occupancy, the dose is estimated as follows:

$$\text{Dose (mrem/yr)} = 90 \frac{\mu\text{R}}{\text{hr}} \times \frac{1\text{hr}}{\text{yr}} \approx 90 \frac{\mu\text{rem}}{\text{yr}} = 0.09 \text{ mrem/yr}$$

Alternatively, it would require an individual to sit in the Flight Trainer cockpit for almost 280 hours to receive a dose of 25 mrem/yr. According to museum personnel, patrons only spend about 15 minutes inside the cockpit of the planes. In summary, based on reasonably foreseeable future uses, it is highly unlikely for an individual to receive a radiological dose above 25 mrem/yr.

4.0 OBSERVATIONS AND RECOMMENDATIONS

The December 2018 initial site visit of the 6151 Portage Road and 3101 East Milham Road Air Zoo properties identified a variety of discrete sources of Ra-226 with radiological doses estimated to be below NRC regulatory limits. This conclusion is based on the following observations:

- The inspection team estimates that more than 100 discrete sources of radium are present, though the total number was not confirmed during the visit.
- Ra-226 was identified in the Link Instrument Flight Trainer, the Curtiss-Wright XP-55 Ascender, the Timm N2T-1 Tutor, the Mikoyan-Gurevich MiG-15, the Douglas KA-3B Sky Warrior, and multiple stored items.
- It would require 18 hours for an individual to receive 25 mrem/yr in the cockpit of the Curtiss-Wright XP-55 Ascender, though the Ascender is not accessible to the public; it would require almost 280 hours for an individual to receive 25 mrem/y in the cockpit of the Flight Trainer, though patrons typically spend only 15 minutes in the seat.
- Stored discrete sources of Ra-226 are located in areas that are away from normal work areas and away from public access.
- Removable contamination was identified at relatively low concentrations on a few stored items, with a maximum of 54.9 disintegrations per minute, noting that scoping surveys were limited to items that were easily accessible at the time.

The regulations in 10 CFR 31.12 require a General License when 1 to 100 discrete sources of radium are present; 10 CFR 30.3 would require Specific License when the provisions of a General License under 10 CFR 31.12 are not met, i.e., when more than 100 discrete sources of radium are present. Following the completion of the initial site visit, Air Zoo officials indicated that the inventory of uninstalled radium luminous items or products would be reduced to less than 100 discrete sources, to meet the provision for a General license. Given the very limited amount of contamination found and the controls in place for the radium-bearing items in storage, a scoping survey in accordance with TI 2800/043 is not recommended.

5.0 REFERENCES

Air Zoo Brochure 2018. https://www.airzoo.org/docs/brochures/air_zoo_brochure_low_res.pdf, Internet site accessed November 2018.

Air Zoo 2009. "History," Air Zoo Aerospace and Science Experience, https://www.airzoo.org/page.php?menu_id=48, Internet site accessed November 2018.

Google Earth Pro 2017. Software, Version 7.3.2.5495 (64-bit), accessed November 2018.

KAHM 1996. *Items to be Disposed*. Letter from Thomas R. Sherman/Kalamazoo Aviation History Museum to Kenneth W. Coble/ Bureau of Environmental and Occupational Health, November 1.

Michigan 1995. *Survey of Walls and Floor and Subsequent Decontamination Effort at the Old Restoration Facility at the Kalamazoo Aviation History Museum*. State of Michigan Department of Public Health, Bureau of Environmental and Occupational Health, December 19.

Michigan 1997. *Kalamazoo Aviation History Museum Radiation Gauge Pickup and Survey*. State of Michigan Department of Environmental Quality, 031116-014-L01, January 15.

Michigan 2000. *Visit to the Flight Center Facility to Remove Radium Gauges and Other Contaminated Items*, State of Michigan Department of Environmental Quality, September 29.

NRC 2018. *Inspection of Facilities Potentially Contaminated with Discrete Radium-226 Sources*, Temporary Instruction 2800/043, Revision 2, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, Washington, D.C., May. (ADAMS Accession No. ML17297B921).

ORAU 2018a. Email between David King/Oak Ridge Associated Universities and Richard Chang/U.S. Nuclear Regulatory Commission, October 26.

ORAU 2018b. Notes on personal communication between Kaitlin Engel/Oak Ridge Associated Universities and U.S. Nuclear Regulatory Commission Teleconference, phone conversation, October 29.

ORAU 2018c. *Field Forms from the December 2018 Survey of the Air Zoo Aerospace and Science Museum in Portage, Michigan*, DCN 5307-TR-09-1; Oak Ridge Associated Universities; Oak Ridge, Tennessee; December 18.

ORISE 2017. *Dose Assessment Technical Basis Document for Potential Exposures to Discrete Sources of Radium-226 and Associated Contamination*, DCN 5289-TR-01-2, Oak Ridge Institute for Science and Education, Oak Ridge, Tennessee, May 30. (ADAMS Accession No. ML17152A204).

APPENDIX A
SURVEY DATA TABLE FROM THE AIR ZOO INITIAL SITE VISIT

Table A-1. Survey Data

Loc #	Smear #	Alpha Plus Beta				Gamma			Notes	
		Removable		Totals		Contact	1-m			
		(net cpm) ^a	(dpm/smear) ^b	(gross cpm)	BKG (net cpm)	(cpm)	(μR/hr)	(μR/hr)		
Link Instrument Flight Trainer and Nearby Desk										
1	R0132	28	–	77,000	410	76,000	680,000	1,400	22	First gauge from left; gauge face is 25 cm ²
2	R0133	29	–	110,000	410	110,000	920,000	900	22	Second gauge from left; gauge face is 25 cm ² ; Ra-226 identified
3	R0134	13	–	5,800	410	5,400	220,000	240	22	Table in front of trainer
4	R0135	24	–	5,300	410	4,900	110,000	130	22	Top of trainer
5	–	–	–	–	–	–	43,000	70	50	Outside of flight trainer
6	R0136	15	–	380,000	410	380,000	1,700,000	2,000	70	Top center gauge; gauge face is 25 cm ² ; Ra-226 identified
7	R0137	45	0.8	120,000	410	120,000	950,000	1,000	70	Top left gauge; gauge face is 25 cm ²
8	R0138	46	1.3	16,000	410	16,000	180,000	150	70	Handle of steering wheel; gauge face is 10 cm ²
9	R0139	27	0.6	2,300	410	1,900	80,000	90	70	Seat
Curtiss-Wright XP-55 Ascender										
10	R0140	19	0.5	190,000	330	190,000	710,000	2,500	1,400	Lower left gauge
11	R0141	35	0.6	290,000	330	290,000	930,000	3,600	1,800	Two gauges center left; left lower center gauge, Ra-226 identified
12	R0142	9	–	140,000	330	140,000	430,000	2,300	1,400	Two gauges left of brake; 1-m measurement at seat
13	R0143	43	1.0	77,000	330	77,000	510,000	800	1,400	Two oxygen gauges and oxygen label; 1-m measurement at seat
14	R0144	54	0.9	100,000	330	100,000	750,000	700	1,400	Lower left camera switch; 1-m measurement at seat
15	R0145	39	6.6	120,000	330	110,000	620,000	500	1,400	Right top panel of switches; 1-m measurement at seat
16	R0146	53	1.9	92,000	330	92,000	570,000	500	1,400	Right side panel of switches; 1-m measurement at seat
17	R0147	52	7.9	360,000	330	360,000	360,000	600	1,400	Painted lever with "M" label; 1-m measurement at seat
18	R0148	26	0.3	–	–	–	–	–	–	NRC requested; outside of canopy; smear only
Douglas SBD-3 Dauntless										
19	R0149	16	1.5	30,000	410	–	20,000	20	6	"Up, Hook, Down" lever
20	R0150	-6	–	15,000	410	–	13,000	11	6	"Elevator" tab
21	R0151	10	–	5,300	410	–	9,700	12	6	Right center gauge; insufficient counts to identify Ra-226
22	R0152	-1	–	2,200	410	–	6,100	6	6	Right side gauge
Timm N2T-1 Tutor										
23	R0153	-25	–	5,800	480	–	98,000	120	80	"M" knob
24	R0154	-1	–	150,000	480	–	2,100,000	2,000	80	Lower middle gauge
25	R0155	-46	–	130,000	480	–	1,100,000	1,600	45	Lower middle gauge, Ra-226 identified
26	R0156	-64	–	4,800	480	–	140,000	100	45	M knob
Mikoyan-Gurevich MiG-15										
27	R0157	-20	–	94,000	460	94,000	–	700	60	Two gauges; front right panel; Ra-226 identified
28	R0158	-10	–	12,000	460	12,000	–	80	60	Right side panel gauge
29	R0159	-8	–	3,700	460	3,200	–	50	60	Gun sight
30	R0160	-27	–	1,500	460	1,000	–	38	13	Exterior of plane
31	R0161	-57	–	–	–	–	–	20	–	Back of seat
Douglas KA-3B Sky Warrior										
32	R0162	-79	2.06	79,000	460	79,000	530,000	700	15	Gauge face is 50 cm ² ; 1-m measurement at seat; Ra-226 identified
East Campus Storage Area										
33	R0163	-23	–	–	–	–	330,000	340	20	Exterior of box; did not open-box taped closed
34	R0164	9	–	–	–	–	600,000	800	50	Exterior of box; did not open-box taped closed
35	R0165	33	–	–	–	–	180,000	190	40	Exterior of box; did not open-box taped closed
36	R0166	-10	–	–	–	–	240,000	290	30	Exterior of box; did not open-box taped closed
37	R0167	-45	–	–	–	–	630,000	700	50	Exterior of box
38	R0168	-1	–	–	–	–	37,000	1,000	50	On foil inside of box
39	R0169	24	–	–	–	–	680,000	1,000	50	Inside of box
40	R0170	2	–	–	–	–	330,000	340	20	Inside lip of box
41	R0171	24	–	–	–	–	240,000	290	30	Inside lip of box
42	R0172	27	–	–	–	–	1,000,000	1,500	60	Smear on paper; Ra-226 identified; box not known to NRC

Loc #	Smear #	Alpha Plus Beta					Gamma			Notes
		Removable		Totals			Contact		1-m	
		(net cpm) ^a	(dpm/smear) ^b	(gross cpm)	BKG	(net cpm)	(cpm)	(μR/hr)	(μR/hr)	
43	R0173	-10	-	-	-	-	620,000	500	60	Smear on inside of box
44	R0174	42	2.4	-	-	-	1,000,000	1,400	100	Box not known to NRC; did not open-box taped closed; Ra-226 identified
45	R0175	4	-	-	-	-	350,000	310	19	Smear on paper; not known to NRC; Ra-226 identified
46	R0176	-11	-	-	-	-	31,000	310	19	Smear on inside of box
Main Campus Archive Area										
47	R0177	-7	-	-	-	-	-	-	-	Inside of white box; item not known to NRC
48	R0178	-4	-	-	-	-	-	-	-	Inside of envelope
49	R0179	13	-	13,000	270	13,000	65,000	150	4	Back of compass pouch; Ra-226 identified
50	R0180	-7	-	-	-	-	950,000	800	23	Outside on bombsight; Ra-226 identified
51	R0181	72	5.2	-	-	-	-	-	-	On bag (44-142 detector would not fit inside bombsight)
52	R0182	23	-	-	-	-	-	1,100	-	Outside of green suitcase containing 19 gauges; not known to NRC
53	R0183	161	54.9	240,000	270	240,000	2,600,000	4,200	150	On highest gauge
54	R0184	44	0.8	-	-	-	-	-	-	Outside edge of seat cushion XP-55; item not elevated after moved away from other items
55	R0185	54	0.5	-	-	-	-	-	-	Outside cardboard box with seat cover XP-55; item not elevated after moved away from other items
56	R0186	13	-	-	-	-	-	-	-	Outside white cardboard box; item not elevated after moved away from other items
57	R0187	-11	-	-	-	-	-	-	-	Outside box of engine gauges
58	R0188	-27	-	-	-	-	-	-	-	On brown paper
59	R0189	-11	-	30,000	390	30,000	620,000	700	38	On gauge in engine gauge box; Ra-226 identified
60	R0190	-62	-	-	-	-	-	-	-	Outside white box with octant
61	R0191	-17	-	-	-	-	-	-	-	On wooden box
62	R0192	-23	-	110,000	390	110,000	1,300,000	2,700	40	On eye piece; Ra-226 identified
63	R0193	-31	-	-	-	-	-	-	-	On outside of white box with navy clock
64	R0194	-13	-	260,000	390	260,000	980,000	1,200	17	On navy clock face in box; Ra-226 identified
65	R0195	-17	-	53,000	390	53,000	-	-	-	Outside white box with sextant; Ra-226 identified
66	R0196	-31	-	42,000	390	41,000	820,000	900	37	White box with sextant; reachable area for total alpha+beta count was 25%
67	R0197	-52	-	-	-	-	-	-	-	Outside wooden box with octant
68	R0198	9	-	240,000	390	240,000	2,600,000	3,300	100	On octant
69	R0199	46	0.5	-	-	-	-	-	-	Outside white box with compensating sight
70	R0200	66	49.5	800,000	390	800,000	1,100,000	2,200	32	On item inside; Ra-226 identified
71	R0201	-35	-	-	-	-	-	-	-	Outside wooden box with sextant
72	R0202	-20	-	28,000	390	28,000	630,000	900	23	On item inside; Ra-226 identified
73	R0203	-46	-	-	-	-	-	-	-	Outside leather bag with sextant
74	R0204	-43	-	69,000	390	68,000	1,400,000	1,600	60	On item inside; Ra-226 identified
75	R0205	-45	-	-	-	-	-	-	-	Outside white box with 2 octants
76	R0206	21	-	110,000	390	110,000	1,700,000	2,100	37	On the octant with the highest activity; Ra-226 identified

^aBased on field counts using the Ludlum model 44-192 plastic scintillator

^bBased on gross alpha-plus-beta counts at a radio-analytical laboratory, when submitted; shown to the nearest 0.1 disintegrations per minute

APPENDIX B
PHOTOGRAPHS FROM THE AIR ZOO INITIAL SITE VISIT



B-1. Mikoyan-Gurevich MiG-15



B-2. Douglas KA-3B Sky Warrior



B-3. Link Instrument Flight Trainer



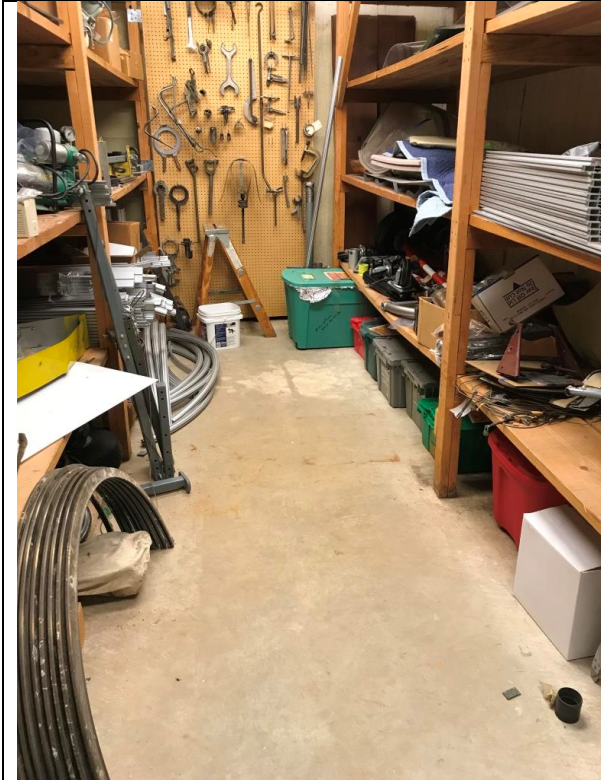
B-4. Douglas SBD-3 Dauntless



B-5. Timm N2T-1 Tutor



B-6. Curtiss-Wright XP-55 Ascender



B-7. Items Stored in East Campus Storage Area (Bottom Right Row)



B-8. Example Item in Main Campus Archive Area



B-9. Wrapped discrete sources of Ra-226 in the East Campus Storage Area



B-10. Case with discrete sources of Ra-226 in the Main Campus Archive Area