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BB.1 Introduction

This document serves as an appendix to Battelle-TBD-6000, *Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals*. This appendix describes the results of document research specific to this site. Where specific information is lacking, research into similar facilities described in the body of this Site Profile is used.

BB.2 Site Description

General Steel Industries performed quality control work for the Atomic Energy Commission (AEC) from 1953-1966. Utilizing a 25 MeV betatron machine, it performed x-rays on uranium ingots and betatron slices to detect metallurgical flaws for the Mallinckrodt Chemical Company[1]. The x-ray films were processed, but not interpreted, at General Steel Industries. The facility is located at 1417 State Street in southwest Granite City, Illinois, northeast of St. Louis, Missouri, east of the Mississippi River. The use of the facility for these services was on an as-needed basis with no indication of the frequency or duration[2].

BB.2.1 Site Activities

During the late 1950s and early 1960s, General Steel Industries was the custodian of a government-owned betatron used to x-ray uranium ingots for the AEC under purchase orders issued by Mallinckrodt Chemical Works. Purchase orders were issued by the Uranium Division, Mallinckrodt Chemical Works, from February 1958 through June 1966, first to General Steel Castings Corporation and later (July 14, 1961 and after) to

General Steel Industries, Inc., at the same address. The ingots were in the form of cylinders 18 to 20 inches in diameter, approximately 18 inches long, and weighing up to 3000 pounds. The betatron x-ray equipment was Government owned. The uranium to be x-rayed was owned by the AEC and provided by Mallinckrodt[3].

BB.2.2 Frequency of uranium X-rays

General Steel Industries work with uranium was performed under purchase orders with Mallinckrodt Chemical Works starting in March of 1958. These purchases orders cover the time period March 1, 1958 through June 30, 1966[4]. These purchase orders indicate that the work was to "X-ray material as requested by Mallinckrodt…". They also contained "Betatron labor charges, including operation and maintenance and all overhead shall be billed at $16.00 per hour." The last purchase order covering the period of July 1, 1965 to June 30, 1966 indicated a billing rate of $35.00 per hour. The purchase orders also indicated that the work was not to exceed a set cost. The first purchase order, covering the period March 1, 1958 to June 30, 1958 stipulated a monthly limit of $500. That purchase order was extended to October 31, 1958 and added $1800 to the total limit (an additional $450 per month). A new purchase order covered the period November 1, 1958 to June 30, 1959 and stipulated a monthly limit of $450 and a total limit of $3600 (equal to $450 per month). The next purchase order covered July 1, 1959 to June 30, 1960 and stipulated a monthly limit of $450 with a total limit of $7200. It should be noted that the total limit does not add up to 12 months at the monthly limit. This is the only purchase order with this conflict. Since these are limits and not estimates, the most limiting of the two values will be used in this appendix which is consistent with purchase orders written both before and after this one.

From that point on, the purchases orders were written annually covering a period of July 1 to June 30 of the next year. All but the last order stipulated a billing rate of $16 per hour. The purchase order starting in 1960 stipulated no total limit. Only a monthly limit of $450 per month was specified. After that, only a total limit was specified. These limits were $7000 for the purchase order starting in 1961, $2000 for the purchase order starting in 1962, and $450 for each of the remaining purchase orders.

From this information, it is possible to determine the maximum hours per year that General Steel Industries spent on operations, maintenance and overhead associated with x-raying uranium for Mallinckrodt Chemical Works. Through June 30, 1961 the limit was generally $450 per month at $16 per hour or 337.5 hrs per year. The remaining years are shown below.

July 1, 1961 to June 30, 1962	437.5 hrs/yr (based on a total limit of $7000)
July 1, 1962 to June 30, 1963	125 hrs/yr (based on a total limit of $2000)
July 1, 1963 to June 30, 1965	28 hrs/yr (based on a total limit of $450)
July 1, 1965 to June 30, 1966	13 hrs/yr (based on a total limit of $450 at $35/hr)

These estimated hours are considered the maximum hours that could have been spent x-raying uranium. These are considered maximum because the purchase orders set these costs as a limit. There is no indication how much of the available funds were actually

used. Also the cost was to include maintenance down time and overhead as well as the cost of film.

For the remainder of the year, it is assumed that various alloys of steel were x-rayed. The operators reported that overtime was very frequent. They indicated the aim of the operators was to get a check over $500 for a two week pay period. This was remembered because the company policy was to not issue a check over $500. When more than that was earned, the company issued two checks, one for $500 and another for the difference. One operator remembered receiving a check for 3 cents. One recollection of the pay-rate during this time period was $3.80 per hour. At that rate, and assuming time and a half after 40 hours worked in a week, it would take approximately 57 hours per week to earn $500. The operators indicated this was a goal but did not indicate how often the goal was achieved. However, they did indicate that an 8 hour work day was "not the norm". They indicated overtime was frequent[5]. Based on this, it will be assumed that the operators worked 2400 hours per year, which is between working straight 40 hours per week and working 57 hours every week.

BB.3 Occupational Medical Dose

No information regarding occupational medical dose was found in any of the site research or CATI materials. Information to be used in dose reconstructions, for which no specific information is available, is provided in ORAUT-OTIB-0006, the dose reconstruction project technical information bulletin covering diagnostic x-ray procedures.

BB.4 Occupation External Dose

No data was found in the Site Research database related to measurements of occupational external dose during AEC work. The AEC work performed at General Steel Industries involved the handling of uranium ingots and other forms of uranium metal during the x-ray process. Since this estimate relies on estimates of exposure times and dose rates, the dose rates for specific types of work in table 6.4 do not apply. For this estimate, the dose rates in table 6.1 for a rectangular ingot will be used for unirradiated uranium metal. This produces the highest dose rate of the potential shapes of uranium metal handled at General Steel Industries.

BB.4.1 Exposure Time

The exposure scenario used to estimate dose at General Steel Industries due to operating the Betatron machine assumes three basic periods of time: setup, x-ray exposure, and take down. Setup is intended to include the time it takes to position the x-ray film and the machine, and to maneuver the material to be x-rayed into position. The take down period includes the time required to remove the x-ray film, process the film, and remove the x-rayed object from the area. The exposure time is the time period in which the betatron is actually operating.

Operator interviews indicate takedown times varied but 30 minutes appeared to be a reasonable average[5]. It was indicated that it could sometimes be done in 15 minutes but not faster because it took time to process the film. This estimate will assume that

takedown took 30 minutes and half of that time was spent at 1 foot from the material being x-rayed. For the remainder of the time, the operator is assumed to be performing other duties in the area at a distance of 1 meter.

Due to the care necessary to position the film and machine, it is assumed that it would take longer to setup the x-ray exposure than to remove the film cassettes. Since little information was available on setup time, and radiation exposures would be higher during takedown time, it is assumed that these times are equal which represents a favorable assumption.

Exposure times recalled by the workers varied somewhat due to the time that has passed and the many different types of items x-rayed through the years. Operators remember exposures of 1 hour, a few hours, a couple hours, etc. [5] however, it is not clear if they were all discussing the same size and shape of uranium products. It appears these times may have been for the large uranium ingots. Exposure times for smaller slices and other shapes would be shorter. It is important to realize at this point that while the Betatron is operating, the operators are outside of the shielded area where dose rates are considerably less than exposure to a freshly x-rayed piece of uranium metal. Therefore, while longer x-ray exposures will result in higher dose rates coming from the uranium, it will also increase the time the operators are assumed to be in a low dose rate area. These competing affects tend to balance out somewhat. This appendix assumes that large pieces of uranium were x-rayed for two hours and smaller slices were x-rayed for less than one hour and thus a reasonable estimate of the average x-ray time is taken to be one hour.

BB.4.2 Skyshine

The betatron building was constructed with 10 foot thick wall to shield operators from radiation while the unit was operating[3]. Given that the walls were only one story high, it is possible for radiation to scatter up and out of the building then scatter again off the air and back down to ground level. This effect is known as skyshine.

External dose rate from skyshine was modeled using Attila software. This is a multi-group deterministic radiation transport environment that can directly use Computer Aided Design (CAD) data and model complex geometry efficiently and accurately to solve large 3-D problems[7]. A drawing and description of the Betatron building was used to determine the dose rate at various points outside the building. The drawing did not include vertical detail but photographs and operator comments indicated that the 10 foot thick walls were only one story high. The building description indicated the roof was a built-up type. Since no detail of the roof was discovered, the model did not contain a second story or a roof. This produces only a slight overestimate since any shielding provided by the built-up roof would be small. The location with the highest modeled dose rate is used in this exposure estimate, which is a dose rate of 0.72 mrem/hr while the Betatron is operating.

BB.4.3 Steel Dose Rates

Operators of the betatron reported that the control panel had a meter that displayed the amount of radiation emitted by the device during an x-ray. This meter was reported to be

capable of being set for a desired exposure in Roentgens (R). Operators reported values of 4.5 hours to accumulate a 10,000 R exposure, 2.5 hours to accumulate a 5,000 R exposure, and 1 hour to accumulate a 1,000 R exposure. These equate to approximately 37, 33, and 17 R/min respectively. Operators also reported machine values of 100 R/min and 250 R/min.

In an interview with Jack Schuetz, who worked with Betatrons for Allis Chalmers, it was learned that the output of the machine was variable and that the 100 R/min was the design maximum value, but that was only achievable in his laboratory when the compensator (or filter) removed.[6] The cone shaped aluminum compensator was used to flatten the beam intensity so that a uniform x-ray could be taken. That is, it shielded the high intensity center of the beam more than the outer edges, thereby creating a relatively uniform exposure over area of the film. This also reduced the x-ray intensity by about a third. In addition, the 100 R/min was measured at a distance of three feet from the beam's focal point. The radiation meter, which was an integral part of the betatron, was calibrated to indicate the uncompensated radiation at three feet from the focal point.

The narrow beam of the betatron required that the distance of the material being x-rayed be greater than three feet to expose an area of reasonable size. For example, a distance of 6 feet was required for an 11" x 14" film. It was reported that common film sizes in use were as large as 17 inches. This is consistent with information provided by the operators at General Steel Industries. They indicated they normally made exposures at either 6 feet or 9 feet and had a string on the machine to measure that distance[5]. This evaluation assumes that all x-ray exposures were made at 6 feet and that the uncompensated exposure rate at 3 feet is 100 R/min.

The high energy x-rays emitted by the Betatron machine can cause non-radioactive components in the material being irradiated to become radioactive through photo-neutron reactions. The build up of radioactive isotopes from this reaction in a large piece of steel from a Betatron x-ray spectrum was determined using a computer program MCNPX 2.5.0[8]. MCNPX is a general-purpose Monte Carlo radiation transport code that utilizes the latest nuclear cross section libraries. This modeling resulted in the determination that one isotope was the major contributor to the initial dose-rate. The isotope, iron-53 (^{53}Fe) is produced from the photon-neutron reaction of iron-54. The half-life of ^{53}Fe is 8.51 minutes and it decays by electron capture. This results in the emission of two 511 keV annihilation photons. A 379 keV photon is also emitted from ^{53}Fe.

MCNPX was next used to model the dose-rate from a large piece of steel that was x-rayed for 60 minutes. The initial dose-rate at the end of the exposure period was calculated to be 0.5 mR/hr at one foot and 0.0668 mR/hr at one meter. After 30 minutes of decay, these dose-rates drop to 0.0433 mR/hr and 0.00578 mR/hr, respectively.

Integrating the dose rates for the 30 minutes following exposure produces a dose of 0.0934 mR at one foot and 0.0125 mR at one meter. Assuming half the time the individual is one foot away and the other half, one meter away, the integrated dose is 0.0529 mR for the 30 minutes following a one hour exposure.

Mr. Schuetz also reported that the Betatron itself is activated by the beam and produced a dose rate of 15 mR/hr that quickly decays to near zero within 15 minutes.[6] Although Mr. Schuetz indicated this was caused by the platinum target becoming radioactive, no isotopes of platinum could be identified to explain this rapid decay. The more likely source of this radiation is the aluminum compensator. This compensator receives the full force of the x-ray beam at very close proximity. This beam can cause the creation of Aluminum-28 (^{28}Al) which has a half-life of 2.25 minutes. This half-life would result in the dose rate decreasing from 15 mR/hr to 0.15 mR/hr in 15 minutes. It would also result in an integrated exposure over 30 minutes of 0.811 mR.

The overall estimate for Betatron x-ray of steel is: 30 minutes setup with no dose; one hour Betatron x-ray exposure due to skyshine at 0.72 mR/hr; and, 30 minutes takedown resulting in 0.864 mR of dose (primarily from activation of the aluminum compensator). This totals 1.58 mR of dose over two hours or a 0.792 mR/hr average dose rate while x-raying steel.

BB.4.4 Uranium Dose Rates

External exposure to radiation during betatron operations with uranium comes from three sources. The uranium metal itself exposes the operators to external radiation while they are in the process of setting up and taking down the shots and moving the piece into and out of the building. The source of exposure while the Betatron is operating would be primarily skyshine from x-rays scattered up and out of the building then down to the operators. Any x-rays penetrating the 10 foot thick shielded walls of the building is also accounted for. The last type of external radiation exposure is from the activation of the uranium itself. This is caused by the photon-neutron reaction of the high energy photons from the 25 MeV x-ray spectrum. External radiation from activation products are actually negligible compared to the dose-rate emitted by the uranium metal itself, however, the photo-fission reaction that also occurs produces short-lived fission products that for a short time increase the external dose rate.

The external dose rate from the uranium itself is applied to both the setup and take down time but not the time the Betatron is operating since the operators are not in the area during this time. The dose rates used are from the rectangular ingot from Table 6.1. The one foot (30.48 cm) and 1 meter dose rates are used with the assumed exposure scenarios discussed earlier.

The dose rate from irradiated uranium was evaluated using MCNPX 2.6c. Several different sizes and shapes of uranium metal were x-rayed at General Steel Industries. Because of this, a large block of uranium metal was evaluated as a bounding condition. The results of the MCNPX evaluation indicated that fission occurs predominately within a few centimeters of the surface being exposed, which indicates a similar result should be obtained regardless of the shape of the uranium piece. It also indicates any shielding provided by the uranium is limited.

The short half-life fission products decay quickly producing more radiation and thus higher dose rates than the longer-lived isotopes. Conversely, the short-lived products produce these higher dose rates for a shorter time. To evaluate the net effect, the dose

rate was determined at 1 foot and 1 meter at various times after the x-ray machine was turned off. The dose–rate as a function of time at the two distances was found to be best expressed by the equations provided below.

$$D_{30}(t) = 0.0793e^{-0.7181\times t_{hrs}} + 0.01e^{-0.0864\times t_{hrs}}$$

$$D_{100}(t) = 0.0107e^{-0.741\times t_{hrs}} + 0.0014e^{-0.0883\times t_{hrs}}$$

These equations describe the dose (in rem/hr) at any time post irradiation. By integrating these equations, the total dose for a period of time post irradiation can be determined. The estimate here assumes the take down time is 30 minutes and that half of the exposure is at 1 foot from the uranium while the remainder is at 1 meter. This results in a dose of 21.7 mrem over the first 30 minutes following irradiation.

Using the methodology in section 6.3 of this Technical Basis Document, the non-penetrating dose to the skin of the forearms and hands can be calculated to be 5.75 R/yr. The non-penetrating dose to the skin of the rest of the body can be calculated to be 0.52 R/yr.

The overall estimate for the Betatron x-ray of uranium thus includes 30 minutes setup at 1.227 mR/hr for 0.613 mR of dose. An additional 0.613 mR is received from the uranium metal during takedown. Also during takedown, 21.7 mR of dose is received from 30 minutes of exposure to the fission product radiation and 0.811 mR from exposure to the activated compensator. Lastly, skyshine from the one hour Betatron x-ray exposure produces an additional 0.72 mR of dose. This totals 24.4 mR of dose over two hours or 12.2 mR/hr average dose-rate while x-raying uranium.

BB.4.5 External Dose Summary

The external photon dose for Betatron operators is summarized in the table below.

	R/yr		
Year	Photon	Skin	Hand and forearms Skin
1953-1960	5.751	1.755	19.406
1961	6.321	2.015	22.281
1962	5.109	1.463	16.172
1963	2.774	0.398	4.399
1964	2.220	0.146	1.610
1965	2.135	0.107	1.179
1966	1.025	0.034	0.374

Half of the photon dose should be entered into IREP as greater than 250 keV photons and the other half as 30 keV and 250 keV photons. Further, since a number of bounding estimates were used (i.e., no maintenance or other down time, operators instantaneously in the area after exposure, etc.) to determine these doses, the values should be considered a constant distribution. Skin doses should be entered into IREP as a constant distribution of electrons greater than 15 keV.

This dose should be used to estimate the dose to radiographers and anyone else that was routinely handling the steel or uranium within 2 hours following the x-ray exposure. While other radiography sources existed at General Steel Industries, the dose estimates in this appendix are considerably higher than those typically received by radiographers. Because of this it is more favorable to assume these employees were always operating the Betatron.

Some employees did not normally work in the Betatron building or with x-rayed steel within 2 hours of exposure. For these employees, the maximum exposure at General Steel Industries would be from the skyshine due to the Betatron. Therefore, the dose rate of 0.72 mR/hr will be assigned to these employees with the assumed work year of 2400 hours per year. This results in an annual photon dose of 1.73 R/yr.

This dose rate is highest very near the Betatron building and lower as the distance from the building is increased. Since this is the maximum exposure outside the building, this dose should be entered into IREP as a constant distribution. The energy should again be considered 50% greater than 250 keV photons and 50% 30 keV to 250 keV photons.

BB.5 Occupation Internal Dose

No data was found related to occupational internal dose during AEC work. In addition, no records of air monitoring were found in the site research database. Since no cutting, machining, or abrading of the uranium was involved, there was a low potential for producing elevated air concentrations of uranium. Of the work processes presented in this Technical Basis Document (TBD), this work process most closely resembles the "Slug Production" process, as described in Section 2.1.5 of this TBD. Occupational Internal Dose from inhalation and ingestion should be calculated and assigned in accordance with Section 7.0 of this Technical Basis Document using the data in Tables 7.8 and 7.9 for the Slug Production process. The data represents worst-case exposures and is favorable to the claimants. However, the intakes assumed in these tables are based on 2000 hours of work per year. Since operators at General Steel Industries did not work with uranium full time, the intakes must be pro-rated. Also, even though these values are the median value, it is important to remember it is the median value for slug production work. This work included some machining of uranium metal while the work at General Steel Industries did not. Therefore, these values should be considered a bounding estimate and assigned a constant distribution.

BB.5.1 Intakes from Fission Products

Intakes of fission products must also be considered. Because there are many different isotopes produced as fission products, it makes it difficult to estimate internal dose from this process. Internal dose from uranium is caused by a low dose-rate delivered over years. Many fission products on the other hand have a relatively short half-life so they do not deliver a dose-rate for a long period of time. Immediately following the one hour x-ray exposure, the concentration of uranium atoms is actually 3.36 trillion times higher than fission product atoms. However, the activity concentration of fission products is approximately 11 times that of the uranium activity concentration. This percentage decreases quickly to less than 10% after 8 hours. The internal dose is determined by the

total number of decays times the energy emitted by those decays. Fission products decay is primarily beta and photon decay and the energy is almost always less than 2 MeV. Meanwhile, uranium decays by alpha decay with energy always greater than 4 MeV. Also, alpha particles are more effective at causing damage. To account for this, the International Commission on Radiological Protection (ICRP) uses a multiplier of 20 named the radiation weighting factor. The weighting factor is used to increase the energy deposited by this factor of 20 to determine dose. Even assuming the worst case 2 to 1 energy ratio, the dose delivered by fission products over the first year after inhalation is approximately 0.005% that of the dose delivered by uranium. Therefore, it is sufficient to estimate the internal dose from fission products by assuming the uranium intake is 1% higher than that listed in Tables 7.8 and 7.9. It should be noted that this is favorable since a) the 2 to 1 energy ratio is actually a favorable assumption, b) uranium will continue to deliver a dose long after the first year after intake while fission products will continue to decrease and c) the radiation weighting factor for alpha radiation is 20 times higher than that of beta and gamma emitting fission products. The increase to 1% is intended to account for the differences in biokinetic models between uranium and the various fission products.

BB.5.2 Intakes from Activation Products in Steel

The purpose of x-raying steel castings was to detect internal flaws. Once found, they could be ground out and repaired. This implied the steel could be ground out soon after the x-ray while it is still radioactive, which would cause radioactive dust to be inhaled by the person grinding the casing. To estimate this intake pathway, the modeled x-ray exposure was again used. This model indicated the ^{53}Fe activity near the surface immediately after the x-ray exposure is 3.13 nCi/gm.

Table 7.5 of this Technical Basis Document lists air concentrations for uranium machining operations. Of the three grinding operations, centerless grinding had the highest results of 4000 to 5000 dpm/m^3. This equates to 3.571 mg/ m^3 to 4.286 mg/ m^3. This estimate will assume the airborne concentration from grinding steel is 4 mg/m^3. Since the grinding could not occur until after the film was processed, it is further assumed that it did not start until 30 minutes after the x-ray exposure ended. If the grinding continued until the activity was completely decayed away, the total activity inhaled would be approximately 0.267 pCi. The maximizing scenario is that the casting is moved out of the betatron building so that the grinding can take place while another piece is being x-rayed. With the exposure scenario described in this appendix, this allows the grinding to start on a freshly x-rayed piece every 2 hours. If 0.267 pCi is inhaled every two hours for 2400 hours per year, the total intake would be 320 pCi. This intake of ^{53}Fe would result in an annual dose of less than one mrem for all organs. Therefore, no internal dose will be assigned from the inhalation of steel.

BB.5.3 Summary of Intakes of Radioactive Material

Inhalation of uranium is based on 198 dpm/m^3 from Table 7.8 of this Technical Basis Document. This value is applied for the number of hours operators were in the Betatron building working with the uranium. It is not applied to the time the Betatron was

operating to x-ray the uranium since operators were excluded from the building during that time.

During the rest of the time the operators were x-raying steel and other materials. Some residual uranium contamination may have been present that could become airborne and cause additional intakes. In order to estimate this, a terminal settling velocity of 0.00075 m/s was used. This is an estimate of the velocity of deposition on surfaces in the building. It was assumed that uranium settled on plant surfaces at a steady rate for the entire time that operators where working with the uranium with no cleaning, tracking, or other removal mechanism. This results in a surface contamination value of 117,000 dpm/m^2 or 1170 dpm/100 cm^2 for the July 1, 1961 to June 30, 1962 time frame. This is the time frame with the most possible hours of uranium work. This is reasonably close to the maximum value of 540 dpm/100 cm^2 measured in a 1989 survey[2]. Therefore, it is assumed that this value existed in the building between uranium operations starting on July 1, 1961 until remediation occurred. Prior to that, a similar calculation results in a contamination level of 90,200 dpm/m^2 which will be used for that time frame. Using a resuspension factor of 1E-6 m^{-1}, these levels of contamination results in a constant airborne concentration of 0.0902 dpm/m^3 and 0.117 dpm/m^3 for the early and later time frames respectively. These level will be applied to operators intakes for all hours they are in the Betatron building for operations not involving uranium.

Also, as discussed in section 5.1, these values are increased by 1% to account for the inhalation of fission products. Ingestion rate must also be included and will be based on this average air intake and OCAS-TIB-009.

The uranium inhalation intakes during the operational period are summarized in the following table. The 1% increase for fission products has been included.

	Uranium Operations	Residual between Operations	Total
Year	dpm/cal. day	dpm/cal. day	dpm/cal. day
1953-1960	110.95	0.62	111.57
1961	127.38	0.69	128.07
1962	92.46	0.82	93.28
1963	25.15	0.90	26.05
1964	9.20	0.92	10.13
1965	6.74	0.92	7.66
1966	4.27	0.93	5.20

NOTE: 1966 values only apply through 6/30/1966

BB.6 Residual Contamination

A survey was performed in the old Betatron building in March 1989[2]. The maximum direct (fixed plus removable) alpha contamination measurement was 540 dpm/100 cm^2. However, calculations in section BB.5.3 of this appendix resulted in a contamination level of 1170 dpm/100 cm^2. This value will be applied to all time frames in the residual contamination period starting on 7/1/1966 and ending 12/31/1993 (when remediation was completed). This results in a uranium inhalation of 0.932 dpm/calendar day. Ingestion

rate must also be included and will be based on this average air intake and OCAS-TIB-009.

This level of contamination would result in an annual external dose of less than 1 mrem per year to most organs. However, the 1989 survey also included a dose rate survey of the building. While most measurements were consistent with background levels of radiation, a vacuum cleaner in one corner measured 90 uR/hr on contact. This results in a radiation dose higher than that from the surface contamination levels calculated above. Assuming someone is in contact with this vacuum cleaner for 2400 hours per year, the resulting dose would be 216 mrem/yr. This value will be assigned to each year of exposure during the residual contamination period as a constant distribution. The energy should be assumed to be 50% greater than 250 keV and 50% 30 to 250 keV.

BB.7 References

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