



Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87185-5400

December 12, 1996

Mr. Joseph J. Holonich, Chief
Uranium Recovery Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards
Mail Stop T7J9
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Holonich:

Enclosed, please find page changes to the Grand Junction Climax Mill Site Completion Report. These page changes address NRC's outstanding issues with the Bess Warehouse and quonset hut. Upon review, please forward your concurrence that the site is complete.

If you have any questions, please contact me at (505) 845-4030.

for Michael J. Abrams
J. M. Pape
Site Manager
Environmental Restoration Division

Enclosure(3)

cc w/enclosure(1):
C. Abrams, NRC

cc w/o enclosure:
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9612180089 961212
PDR WASTE
WM-54 PDR

170061

WM-54
1/1 NLO4

ATTACHMENT 1

Radiological Assessment of Grand Junction Bess Warehouse Residual Contamination

Decontamination efforts were performed on the exterior of the Bess Warehouse in Grand Junction, CO to remove radioactive materials. Follow-up surveys indicate that some fixed contamination remains at levels above established total contamination limits. Based on previous characterization information, it is believed that the material is uranium mill tailings. The presence of both beta-gamma and alpha radiations (found in earlier surveys) indicates that the contamination is likely not a single radionuclide.

A radiological assessment was performed to determine potential doses to the public in the event of unrestricted release of the building. The risk assessment methodology employed here is based on the calculation of the number of hours required to receive a dose equal to the limits. The total effective dose equivalent (TEDE) was modeled using the RESRAD-BUILD code (version 2.10) developed by Argonne National Laboratories. Shallow dose to the skin was modeled using the VARSKIN Mod 2 code. A comparison was also made to applicable contamination limits.

The regulatory dose limits, contamination limits, and recommended dose limits that apply to this situation are taken from DOE Order 5400.5, Radiation Protection of the Public and Environment, and from recommendations of the ICRP and NCRP. The TEDE limit in DOE Order 5400.5 is 100 mrem per year. The Order further restricts the annual dose from airborne radioactivity to 10 mrem.

For unrestricted release of materials, the limits in Order 5400.5 are 1,000 dpm/100 cm² removable alpha, 1,000 dpm/100 cm² removable beta-gamma, 5,000 dpm/100 cm² total alpha (removable + fixed), and 5,000 dpm/100 cm² total beta-gamma (removable + fixed). The UMTRA Project has been instructed by DOE (Attachment 1) to use these contamination limits unless there is evidence that the majority of contamination is Ra-226 or Th-230, in which case more restrictive limits apply. Order 5400.5 also states that the average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm (0.4 in).

Although no shallow dose regulatory limit exists for members of the public, the ICRP (Publication 60) and the NCRP (Report 91) both recommend limiting shallow dose to the skin to 5,000 mrem per year for members of the public.

For all calculations, the maximum fixed beta-gamma measurement found on exterior surfaces less than approximately six foot above ground was used. This approach is conservative in that the maximum contamination level is considerably higher than the overall average for the building. It is appropriate because realistic exposure scenarios are best modeled using only accessible areas (less than six foot above ground). The maximum beta-gamma measurement was then correlated to specific radionuclide contamination levels using the tailings matrix alpha- and beta- factors from Attachment 2 (Reif 1992).

The highest fixed beta-gamma contamination level on the accessible exterior of the Bess Warehouse is approximately 10,740 dpm/100 cm². Several areas along the exterior of the structure exhibit contamination levels of this magnitude. Fixed alpha contamination is estimated

(see the footnote to Table 2) to be 15,340 dpm/100 cm². To determine the contamination level for a specific radionuclide (e.g., Th-234), the following formula is used:

$$\frac{10740 \text{ dpm}}{100 \text{ cm}^2} \times \frac{\text{pCi}}{2.22 \text{ dpm}} \times \frac{10^{-6} \text{ } \mu\text{Ci}}{\text{pCi}} \times 1.93 \times 10^{-2} = 9.3 \times 10^{-7} \frac{\text{ } \mu\text{Ci}}{\text{cm}^2}$$

All radionuclide contamination levels were determined with this method, and the results in Attachment 3 were used in the subsequent models.

The RESRAD-BUILD model was conservative in that it was assumed that a person was exposed 1 foot from a large wall contaminated with the radionuclides in Attachment 3. It was also assumed that 50% of the contamination would be removed over the course of 10 years, and that all of the removed contamination would be available in the air. Attachment 4 contains the model input parameters and results. A summary of the risk assessment can be found in Attachment 5.

For shallow dose assessment, modeling methodology was conservative in that the maximum contamination level measured was assumed to be spread over a 5-m² area, with a target area of 100 cm². Skin depth was estimated to be 7 mg/cm² for the shallow dose equivalent calculation. The separation of source and receptor was 304.8 mm (1 ft). The results from this analysis can be found in Attachment 3.

Based on the modeling assumptions and methodology, it can be seen that no annual dose limits or recommendations will be exceeded. These estimates are conservative in that the reduction in source term due to weathering and radioactive decay over time is not considered. Table 1 gives the number of hours necessary in the exposure condition (1 foot from wall) for a given limit to be reached. Note that the average year contains 8,766 hours, and that continuous exposure would result in a dose less than 20% of any limit.

Table 1. Bess Warehouse Risk Assessment		
Annual Limit	mrem	hours required
DOE 5400.5 TEDE	100	54,000
DOE 5400.5 Airborne	10	1,415,000
ICRP Skin (recommended)	5000	53,000

The existing maximum contamination levels on Bess Warehouse are compared to the unrestricted release criteria listed in DOE Order 5400.5 in Table 2. The maximum contamination level is four times greater than the allowable residual contamination. Note that the maximum contamination level is considerably greater than the overall average for the building. The calculated maximum shallow dose rate at 1 cm (0.4 in) is 0.3 mrad/h, less than the 1.0 mrad/h recommended threshold in Order 5400.5.

To evaluate the dose from demolition of the warehouse, the RESRAD-BUILD code was again used. Demolition model parameters were the same as used in the TEDE and inhalation dose calculation, except all of the contamination was assumed to become airborne over the course of

two days. The value of 10,740 dpm/100 cm² was used to be conservative but reasonable. The demolition TEDE was calculated as 1.3 mrem, with inhalation the main pathway (Attachment 6).

<i>Table 2. Comparison of Existing Contamination Levels to Unrestricted Release Criteria</i>				
<i>Bess Warehouse (max dpm/100 cm²)</i>			<i>DOE Order 5400.5 Allowable Contamination*</i> (dpm/100 cm ²)	
	<i>Removable</i>	<i>Fixed</i>	<i>Removable</i>	<i>Total</i>
<i>alpha**</i>	124	31,180	1000	5000
<i>beta-gamma</i>	87	21,830	1000	5000
<i>* Contamination limits for uranium and its associated decay products</i>				
<i>** Estimated using beta-gamma measurements and a beta-gamma to alpha ratio of 0.7</i>				

Key Points:

- Based on modeling, no member of the public could receive doses that approach regulatory or recommended limits.
- Demolition of the building does not appear to pose a radiological concern.
- The fixed contamination levels on the Bess Warehouse exceed the allowable contamination levels for unrestricted release found in DOE Order 5400.5.

References

Reif, R.H.; Turner, J.B.; Carlson, D.S. Uranium in vitro bioassay action level used to screen workers for chronic inhalation intakes of uranium mill tailings. Health Phys. 63:398-401; 1992.

Department of Energy

MK-FERGUSON CO. Albuquerque Field Office
 ALBUQUERQUE UMTRA Project Office

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to: James G. Oldham, Project Director, MK-F

A recent review of UMTRA Project proposed surface contamination release limits by the DOE-HQ, Air Water and Radiation Division were found to be unacceptable. Therefore, you are directed to use the limits specified in Nuclear Regulatory Commission Regulatory Guide 1.86, Table 1 for UMTRA Project work. Contamination at UMTRA sites should be considered to be U-nat, U-235, U-238, and associated decay products. In extreme cases where a majority of the activity of the contamination is known to be from a specific associated decay product, such as Ra-226 or Th-230, the limits for those specific isotopes may be used. This guidance will be incorporated into the next revision of the UMTRA Project ES&H Plan.

Should you have any questions, please contact Charlene Esparza-Baca at 845-5664.

Frank D. Bosiljevac
Frank D. Bosiljevac
Technical Support Group Leader
Uranium Mill Tailings Remedial
Action Project Office

cc:
C. Soden, SPD, AL
F. Sprague, FPD, AL

O	DIST	REP	INFO	DIST
JTO				SOM
GXB			✓	MWHP
WAZ				RAP
REC			✓	DSC
WTD				DRS/MAKE
JBH				GG/PD
WPH				DLB
AJCT				TBS
C/D				DPB
P/W				
SIS/PC				

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tailings matrix	Bq / unit tailings	beta	alpha	beta-Bq /unit	alpha-Bq /unit	beta factor*	alpha factor**
U-238	0.083		1		8.30E-02		1.29E-02
Th-234	0.083	1		8.30E-02		1.93E-02	
Pa-234	0.083	1		8.30E-02		1.93E-02	
U-234	0.083		1		8.30E-02		1.29E-02
Th-230	1		1		1.00E+00		1.55E-01
Ra-226	1		1		1.00E+00		1.55E-01
Rn-222	1		1		1.00E+00		1.55E-01
Po-218	1		1		1.00E+00		1.55E-01
Pb-214	1	1		1.00E+00		2.32E-01	
Bi-214	1	1		1.00E+00		2.32E-01	
Po-214	1		1		1.00E+00		1.55E-01
Pb-210	1	1		1.00E+00		2.32E-01	
Bi-210	1	1		1.00E+00		2.32E-01	
Po-210	1		1		1.00E+00		1.55E-01
U-235	0.003868		1		3.87E-03		6.00E-04
Th-231	0.003868	1		3.87E-03		8.97E-04	
Pa-231	0.0466		1		4.66E-02		7.23E-03
Ac-227	0.0466	1		4.66E-02		1.08E-02	
Th-227	0.0466		1		4.66E-02		7.23E-03
Ra-223	0.0466		1		4.66E-02		7.23E-03
Rn-219	0.0466		1		4.66E-02		7.23E-03
Po-215	0.0466		1		4.66E-02		7.23E-03
Pb-211	0.0466	1		4.66E-02		1.08E-02	
Bi-211	0.0466		1		4.66E-02		7.23E-03
Tl-207	0.0466	1		4.66E-02		1.08E-02	
sum	10.759	10	15	4.310	6.449		

* fraction of beta-Bq per unit tailings divided by total beta-Bq

** fraction of alpha-Bq per unit tailings divided by total alpha-Bq

Bess

10740 dpm/100cm² beta
4.84E-05 $\mu\text{Ci}/\text{cm}^2$ 15300 dpm/100cm² alpha
6.89E-05 $\mu\text{Ci}/\text{cm}^2$ VARSKIN Mod2
source area = 5 m²
@1ft
rad/h@1cm
rad/h

	beta $\mu\text{Ci}/\text{cm}^2$	alpha $\mu\text{Ci}/\text{cm}^2$		
U-238		8.87E-07		
Th-234	9.32E-07		0.00E+00	1.02E-06
Pa-234	9.32E-07		4.32E-06	8.58E-06
U-234		8.87E-07		
Th-230		1.07E-05		
Ra-226		1.07E-05		
Rn-222		1.07E-05		
Po-218		1.07E-05		
Pb-214	1.12E-05		2.16E-05	1.18E-04
Bi-214	1.12E-05		3.82E-05	8.68E-05
Po-214		1.07E-05		
Pb-210	1.12E-05		0.00E+00	0.00E+00
Bi-210	1.12E-05		3.09E-05	8.33E-05
Po-210		1.07E-05		
U-235		4.13E-08		
Th-231	4.34E-08		0.00E+00	0.00E+00
Pa-231		4.98E-07		
Ac-227	5.23E-07			
Th-227		4.98E-07		
Ra-223		4.98E-07		
Rn-219		4.98E-07		
Po-215		4.98E-07		
Pb-211	5.23E-07			
Bi-211		4.98E-07		
Tl-207	5.23E-07			

sum

9.50E-05 rad/h

2.98E-01 mrad/h

ICRP 60 recommended skin
dose limit to public:

5 rem

time to reach limit:

53000 hours

** RESRAD-BUILD Program Output, Version 2.10 11/06/96 11:22 Page: 0- 0 : 1 **

Title : Default Case for RESRAD-BUILD

Input File : BESS.DAT

```

#####
#####
eee                                     eee
eee   RESRAD-BUILD Table of Contents   eee
eee                                     eee
#####
#####

```

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    Dose by Pathway Detail..... 1-3
    Dose by Nuclide Detail..... 1-4
Full Summary..... F-1

```


RESRAD-BUILD Input Parameters

Number of Sources : 1
Number of Receptors: 1
Total Time : 3.650000E+02 days
Fraction Inside : 1.000000E+00

continuous exposure
$$365 \frac{d}{y}$$

***** Receptor Information *****

Receptor	Room	x	y	z	FracTime	Inhalation	Ingestion(Dust)
		[m]	[m]	[m]		[m3/day]	[m2/hr]
1	1	22.860	45.415	1.800	1.000	1.80E+01	1.00E-04

***** Receptor-Source Relationship *****

Recept	Source	1

	Density	Thickness Or
	[g/cm3]	[cm]
1	2.40E+00	0.00E+00 RT

***** Building Information *****

Building Air Exchange Rate: 1.00E+02 1/hr

Height[m]	Air Exchanges [m3/hr]	
Area [m2]		

	*	*
	*	*
	*	*
H1: 9.144	* Room 1	<=Q01: 2.06E+07
	* LAMBDA: 1.00E+02	* Q10 : 2.06E+07
Area*****	*	*
	*	*

AER of 100 hr⁻¹ ⇒ open air
 building with
 2.84 mph breeze

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-06 [1/s]

Source Information

Source: 1
Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57[m]
Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y
Pathway ::
Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 1.000E+00
Removable fraction: 5.000E-01
Time to Remove: 3.650E+03 [day]

Radon Release Fraction: 1.000E-01

Contamination::

Nuclide Concentration		Dose Conversion Factors					
		Ingestion	Inhalation	External	External	Submersion	
				(Surface)	(Volume)		
[pCi/m2]	[mrem/pCi]	[mrem/pCi]	[mrem/yr/ (pCi/m2)]	[mrem/yr/ (pCi/m2)]	[mrem/yr/ (pCi/m3)]	[mrem/yr/ (pCi/m3)]	
U-238	8.890E+03	2.500E-04	1.200E-01	3.530E-06	9.510E-08	1.600E-04	
U-235	4.140E+02	2.500E-04	1.200E-01	1.950E-05	4.740E-07	9.030E-04	
U-234	8.890E+03	2.600E-04	1.300E-01	8.750E-08	2.520E-10	8.930E-07	
PA-231	4.990E+03	1.100E-02	1.300E+00	4.760E-06	1.190E-07	2.010E-04	
TH-230	1.070E+05	5.300E-04	3.200E-01	8.780E-08	7.570E-10	2.040E-06	
AC-227	5.230E+03	1.500E-02	1.700E+00	4.530E-05	1.260E-06	2.160E-03	
RA-226	1.070E+05	1.100E-03	7.900E-03	1.940E-04	7.000E-06	1.040E-02	
PB-210	1.120E+05	6.700E-03	2.100E-02	4.140E-07	3.820E-09	1.430E-05	

Assessment for Time: 1
Time = 0.00E+00 yr

Source Information

Source: 1
Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57 [m]
Geometry:: Type: Area Area: 4.18E+02 [m2] Direction: y
Pathway ::
Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 1.000E+00
Removable fraction: 5.000E-01
Time to Remove: 3.650E+03 [day]

50% of contamination
becomes airborne over 10 y

Contamination::	Nuclide	Concentration [pCi/m2]
	U-238	8.890E+03
	U-235	4.140E+02
	U-234	8.890E+03
	PA-231	4.990E+03
	TH-230	1.070E+05
	AC-227	5.230E+03
	RA-226	1.070E+05
	PB-210	1.120E+05

RESRAD-BUILD Dose Tables

Receptor Point-Source Doses
[mrem]

	Source	Total
	1	
Receptor 1	1.6E+01	1.6E+01
Total	1.6E+01	1.6E+01

Title : Default Case for RESRAD-BUILD

Input File : BESS.DAT Evaluation Time: 0.000000 years

Pathway Detail of Doses

[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	1.62E+01	4.26E-06	1.31E-07	6.19E-02	5.82E-06	2.16E-04
Total	1.62E+01	4.26E-06	1.31E-07	6.19E-02	5.82E-06	2.16E-04

$$\text{All pathways} = \frac{16.2621 \text{ mrem}}{365 \text{ days}} \times \frac{1 \text{ d}}{24 \text{ h}} \times 10^3 \frac{\mu\text{rem}}{\text{mrem}}$$

$$= 1.86 \frac{\mu\text{rem}}{\text{h}}$$

to get 100 mrem

$$\text{requires: } \frac{100 \text{ mrem}}{1.86 \text{ E-}3 \frac{\mu\text{rem}}{\text{h}}} = 54000 \text{ h}$$

a year has 8760 h

Nuclide Detail of Doses
[mrem]

Source: 1

Nuclide Receptor		Total
1		
U-238		
U-238	2.80E-02	2.80E-02
U-235		
U-235	7.36E-03	7.36E-03
U-234		
U-234	2.03E-03	2.03E-03
PA-231		
PA-231	2.67E-02	2.67E-02
TH-230		
TH-230	3.83E-02	3.83E-02
AC-227		
AC-227	2.30E-01	2.30E-01
RA-226		
RA-226	1.58E+01	1.58E+01
PB-210		
PB-210	5.83E-02	5.83E-02

Pathway Detail of Doses
eeeeeeeeeeeeeeeeeeeeeeeeeeeeee
[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	1.53E+01	4.26E-06	1.31E-07	6.19E-02	5.53E-06	2.16E-04
Total	1.53E+01	4.26E-06	1.31E-07	6.19E-02	5.53E-06	2.16E-04

Title : Default Case for RESRAD-BUILD

Input File : BESS.DAT Evaluation Time: 2.00000 years

Pathway Detail of Doses
=====

[mrem]

Source: 1							
Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion	
1	1.45E+01	4.26E-06	1.31E-07	6.18E-02	5.24E-06	2.15E-04	
Total	1.45E+01	4.26E-06	1.31E-07	6.18E-02	5.24E-06	2.15E-04	

Pathway Detail of Doses
[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	1.29E+01	4.26E-06	1.31E-07	6.17E-02	4.65E-06	2.15E-04
Total	1.29E+01	4.26E-06	1.31E-07	6.17E-02	4.65E-06	2.15E-04

Title : Default Case for RESRAD-BUILD

Input File : BESS.DAT Evaluation Time: 6.00000 years

Pathway Detail of Doses
eeeeeeeeeeeeeeeeeeee
[mrem]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	1.13E+01	4.26E-06	1.31E-07	6.17E-02	4.07E-06	2.15E-04
Total	1.13E+01	4.26E-06	1.31E-07	6.17E-02	4.07E-06	2.15E-04

Pathway Detail of Doses
=====

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	9.69E+00	4.26E-06	1.31E-07	6.16E-02	3.49E-06	2.14E-04
Total	9.69E+00	4.26E-06	1.31E-07	6.16E-02	3.49E-06	2.14E-04

** RESRAD-BUILD Program Output, Version 2.10 11/06/96 11:22 Page: 3- 3 : 15 **
 Title : Default Case for RESRAD-BUILD
 Input File : BESS.DAT Evaluation Time: 10.0000 years

Pathway Detail of Doses
 ~~~~~  
 [mrem]

|           |  |          |            |           |            |          |           |
|-----------|--|----------|------------|-----------|------------|----------|-----------|
| Source: 1 |  | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
| Receptor  |  | 8.07E+00 | 0.00E+00   | 0.00E+00  | 0.00E+00   | 2.91E-06 | 0.00E+00  |
| 1         |  |          |            |           |            |          |           |
| Total     |  | 8.07E+00 | 0.00E+00   | 0.00E+00  | 0.00E+00   | 2.91E-06 | 0.00E+00  |

## RESRAD-BUILD 2.10

Bess Warehouse

Pathway Detail of Doses at  $t = 0$  (mrem)

| External          | Deposition        | Immersion         | Inhalation        | Radon             | Ingestion         |
|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| $1.62\text{E}+01$ | $4.26\text{E}-06$ | $1.31\text{E}-07$ | $6.19\text{E}-02$ | $5.82\text{E}-06$ | $2.16\text{E}-04$ |

All Pathways Combined:

 $1.63\text{E}+01$  mrem $1.86\text{E}-03$  mrem/h

limit:

100 mrem

time to reach limit:

54000 hours

Inhalation Pathway:

 $6.19\text{E}-02$  mrem $7.07\text{E}-06$  mrem/h

limit:

10 mrem

time to reach limit:

1415000 hours

Input File : BESSDEMO.DAT

## Demolition

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#####
#####

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|                                   |     |
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| Receptor-Source Dose Summary..... | I-2 |
| Dose by Pathway Detail.....       | I-3 |
| Dose by Nuclide Detail.....       | I-4 |
| Full Summary.....                 | F-1 |



RESRAD-BUILD Input Parameters

Number of Sources : 1  
Number of Receptors: 1  
Total Time : 2.000000E+00 days  
Fraction Inside : 1.000000E+00

Receptor Information

| Receptor | Room | x<br>[m] | y<br>[m] | z<br>[m] | FracTime | Inhalation<br>[m3/day] | Ingestion(Dust)<br>[m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1        | 1    | 22.860   | 45.415   | 1.800    | 1.000    | 1.80E+01               | 1.00E-04                   |

Receptor-Source Relationship

| Recept               | Source   | 1           |
|----------------------|----------|-------------|
| Density Thickness Or |          |             |
|                      | [g/cm3]  | [cm]        |
| 1                    | 2.40E+00 | 0.00E+00 RT |

\*\*\*\*\* Building Information \*\*\*\*\*

Building Air Exchange Rate: 1.00E+02 1/hr

| Height [m] | Air Exchanges [m3/hr] |                  |
|------------|-----------------------|------------------|
| Area [m2]  |                       |                  |
|            | *****                 |                  |
|            | *                     | *                |
|            | *                     | *                |
|            | *                     | <=Q01: 2.06E+07  |
| H1: 9.144  | Room 1                | * Q10 : 2.06E+07 |
|            | LAMBDA: 1.00E+02      | *                |
| Area*****  | *                     | *                |
|            | *                     | *                |
|            | *****                 |                  |

Deposition velocity: 1.00E-02 [m/s]    Resuspension Rate: 5.00E-06 [1/s]

\*\* RESRAD-BUILD Program Output, Version 2.10 11/11/96 10:44 Page: 0- 3 : 4 \*\*  
 Title : Default Case for RESRAD-BUILD  
 Input File : BESSDEMO.DAT

Source Information

Source: 1

Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57[m]  
 Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y  
 Pathway ::  
 Direct Ingestion Rate: 0.000E+00 [1/hr]  
 Fraction released to air: 1.000E+00  
 Removable fraction: 1.000E+00  
 Time to Remove: 2.000E+00 [day]  
 Radon Release Fraction: 1.000E-01

Contamination:

| Nuclide | Concentration<br>[pCi/m2] | Dose Conversion Factors |                          |                                                 |                                                |                                      |
|---------|---------------------------|-------------------------|--------------------------|-------------------------------------------------|------------------------------------------------|--------------------------------------|
|         |                           | Ingestion<br>[mrem/pCi] | Inhalation<br>[mrem/pCi] | External<br>(Surface)<br>[mrem/yr/<br>(pCi/m2)] | External<br>(Volume)<br>[mrem/yr/<br>(pCi/m3)] | Submersion<br>[mrem/yr/<br>(pCi/m3)] |
| U-238   | 8.890E+03                 | 2.500E-04               | 1.200E-01                | 3.530E-06                                       | 9.510E-08                                      | 1.600E-04                            |
| U-235   | 4.140E+02                 | 2.500E-04               | 1.200E-01                | 1.950E-05                                       | 4.740E-07                                      | 9.030E-04                            |
| U-234   | 8.890E+03                 | 2.600E-04               | 1.300E-01                | 8.750E-08                                       | 2.520E-10                                      | 8.930E-07                            |
| PA-231  | 4.990E+03                 | 1.100E-02               | 1.300E+00                | 4.760E-06                                       | 1.190E-07                                      | 2.010E-04                            |
| TH-230  | 1.070E+05                 | 5.300E-04               | 3.200E-01                | 8.780E-08                                       | 7.570E-10                                      | 2.040E-06                            |
| AC-227  | 5.230E+03                 | 1.500E-02               | 6.700E+00                | 4.530E-05                                       | 1.260E-06                                      | 2.160E-03                            |
| RA-226  | 1.070E+05                 | 1.100E-03               | 7.900E-03                | 1.940E-04                                       | 7.000E-06                                      | 1.040E-02                            |
| PB-210  | 1.120E+05                 | 6.700E-03               | 2.100E-02                | 4.140E-07                                       | 3.820E-09                                      | 1.430E-05                            |

Title : Default Case for RESRAD-BUILD

Input File : BESSDEMO.DAT      Evaluation Time: 0.000000      years

```

=====
Assessment for Time: 1     
Time =0.00E+00 yr     
=====

```

Source Information

Source: 1

Location:: Room : 1    x: 22.86    y: 45.72    z: 4.57 [m]

Geometry:: Type: Area      Area:4.18E+02 [m2]    Direction: y

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E+00

Removable fraction: 1.000E+00

Time to Remove: 2.000E+00 [day]

| Contamination:: | Nuclide | Concentration<br>[pCi/m2] |
|-----------------|---------|---------------------------|
|                 | U-238   | 8.890E+03                 |
|                 | U-235   | 4.140E+02                 |
|                 | U-234   | 8.890E+03                 |
|                 | PA-231  | 4.990E+03                 |
|                 | TH-230  | 1.070E+05                 |
|                 | AC-227  | 5.230E+03                 |
|                 | RA-226  | 1.070E+05                 |
|                 | PB-210  | 1.120E+05                 |

Title : Default Case for RESRAD-BUILD

Input File : BESSDEMO.DAT Evaluation Time: 0.000000 years

Pathway Detail of Doses

eeeeeeeeeeeeeeeeeeeeeeeeeeee

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 8.85E-02 | 8.51E-05   | 2.62E-06  | 1.24E+00   | 3.20E-08 | 4.32E-03  |
| Total    | 8.85E-02 | 8.51E-05   | 2.62E-06  | 1.24E+00   | 3.20E-08 | 4.32E-03  |

Title : Default Case for RESRAD-BUILD

Input File : BESSDEMO.DAT Evaluation Time: 0.000000 years

Nuclide Detail of Doses

\*\*\*\*\*

[mrem]

Source: 1

| Nuclide | Receptor | Total    |
|---------|----------|----------|
|         | 1        |          |
| U-238   |          |          |
| U-238   | 1.64E-02 | 1.64E-02 |
| U-235   |          |          |
| U-235   | 7.98E-04 | 7.98E-04 |
| U-234   |          |          |
| U-234   | 1.76E-02 | 1.76E-02 |
| PA-231  |          |          |
| PA-231  | 9.92E-02 | 9.92E-02 |
| TH-230  |          |          |
| TH-230  | 5.22E-01 | 5.22E-01 |
| AC-227  |          |          |
| AC-227  | 5.35E-01 | 5.35E-01 |
| RA-226  |          |          |
| RA-226  | 1.00E-01 | 1.00E-01 |
| PB-210  |          |          |
| PB-210  | 3.92E-02 | 3.92E-02 |

\*\* RESRAD-BUILD Program Output, Version 2.10 11/11/96 10:44 Page: 0- 0 : 1 \*\*

Title : Default Case for RESRAD-BUILD

Input File : BESSDEMO.DAT

Demolition

```

=====
=====
eee                                     eee
eee   RESRAD-BUILD Table of Contents   eee
eee                                     eee
=====
=====

```

```

Input Parameters..... 0-1
For Each Time (I) :.....
  Time Specific Parameters..... I-1
  Receptor-Source Dose Summary..... I-2
  Dose by Pathway Detail..... I-3
  Dose by Nuclide Detail..... I-4
Full Summary..... F-1

```

RESRAD-BUILD Input Parameters

Number of Sources : 1  
Number of Receptors: 1  
Total Time : 2.000000E+00 days  
Fraction Inside : 1.000000E+00

Receptor Information

| Receptor | Room | x<br>[m] | y<br>[m] | z<br>[m] | FracTime | Inhalation<br>[m3/day] | Ingestion(Dust)<br>[m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1        | 1    | 22.860   | 45.415   | 1.800    | 1.000    | 1.80E+01               | 1.00E-04                   |

Receptor-Source Relationship

| Recept               | Source   | 1           |
|----------------------|----------|-------------|
| Density Thickness Or |          |             |
| [g/cm3] [cm]         |          |             |
| 1                    | 2.40E+00 | 0.00E+00 RT |



Building Information

Building Air Exchange Rate: 1.00E+02 1/hr

| Height[m] | Air Exchanges [m3/hr] |                 |
|-----------|-----------------------|-----------------|
| Area [m2] |                       |                 |
|           | *****                 |                 |
|           | *                     | *               |
|           | *                     | *               |
|           | *                     | <=Q01: 2.06E+07 |
| H1: 9.144 | Room 1                | Q10 : 2.06E+07  |
|           | LAMBDA: 1.00E+02      |                 |
| Area***** | *                     | *               |
|           | *                     | *               |
|           | *****                 |                 |

Deposition velocity: 1.00E-02 [m/s]    Resuspension Rate: 5.00E-06 [1/s]

Source Information

Source: 1

Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57[m]  
Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y  
Pathway ::  
Direct Ingestion Rate: 0.000E+00 [1/hr]  
Fraction released to air: 1.000E+00  
Removable fraction: 1.000E+00  
Time to Remove: 2.000E+00 [day]  
  
Radon Release Fraction: 1.000E-01

Contamination:

| Nuclide Concentration |            | Dose Conversion Factors                           |                        |                        |                        |                        |  |
|-----------------------|------------|---------------------------------------------------|------------------------|------------------------|------------------------|------------------------|--|
|                       |            | Ingestion Inhalation External External Submersion |                        |                        |                        |                        |  |
|                       |            | (Surface) (Volume)                                |                        |                        |                        |                        |  |
| [pCi/m2]              | [mrem/pCi] | [mrem/pCi]                                        | [mrem/yr/<br>(pCi/m2)] | [mrem/yr/<br>(pCi/m3)] | [mrem/yr/<br>(pCi/m3)] | [mrem/yr/<br>(pCi/m3)] |  |
| U-238                 | 8.890E+03  | 2.500E-04                                         | 1.200E-01              | 3.530E-06              | 9.510E-08              | 1.600E-04              |  |
| U-235                 | 4.140E+02  | 2.500E-04                                         | 1.200E-01              | 1.950E-05              | 4.740E-07              | 9.030E-04              |  |
| U-234                 | 8.890E+03  | 2.600E-04                                         | 1.300E-01              | 8.750E-08              | 2.520E-10              | 8.930E-07              |  |
| PA-231                | 4.990E+03  | 1.100E-02                                         | 1.300E+00              | 4.760E-06              | 1.190E-07              | 2.010E-04              |  |
| TH-230                | 1.070E+05  | 5.300E-04                                         | 3.200E-01              | 8.780E-08              | 7.570E-10              | 2.040E-06              |  |
| AC-227                | 5.230E+03  | 1.500E-02                                         | 6.700E+00              | 4.530E-05              | 1.260E-06              | 2.160E-03              |  |
| RA-226                | 1.070E+05  | 1.100E-03                                         | 7.900E-03              | 1.940E-04              | 7.000E-06              | 1.040E-02              |  |
| PB-210                | 1.120E+05  | 6.700E-03                                         | 2.100E-02              | 4.140E-07              | 3.820E-09              | 1.430E-05              |  |

Title : Default Case for RESRAD-BUILD

Input File : BESSDEMO.DAT Evaluation Time: 0.000000 years

```

=====
Assessment for Time: 1
Time =0.00E+00 yr
=====

```

Source Information

Source: 1

Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57 [m]

Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y

Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]

Fraction released to air: 1.000E+00

Removable fraction: 1.000E+00

Time to Remove: 2.000E+00 [day]

| Contamination:: | Nuclide | Concentration<br>[pCi/m2] |
|-----------------|---------|---------------------------|
|                 | U-238   | 8.890E+03                 |
|                 | U-235   | 4.140E+02                 |
|                 | U-234   | 8.890E+03                 |
|                 | PA-231  | 4.990E+03                 |
|                 | TH-230  | 1.070E+05                 |
|                 | AC-227  | 5.230E+03                 |
|                 | RA-226  | 1.070E+05                 |
|                 | PB-210  | 1.120E+05                 |

Title : Default Case for RESRAD-BUILD

Input File : BESSDEMO.DAT      Evaluation Time: 0.000000      years

Pathway Detail of Doses

#####

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 8.85E-02 | 8.51E-05   | 2.62E-06  | 1.24E+00   | 3.20E-08 | 4.32E-03  |
| Total    | 8.85E-02 | 8.51E-05   | 2.62E-06  | 1.24E+00   | 3.20E-08 | 4.32E-03  |

Title : Default Case for RESRAD-BUILD

Input File : BESSDEMO.DAT      Evaluation Time:    0.000000    years

Nuclide Detail of Doses

\*\*\*\*\*

[mrem]

Source: 1

| Nuclide | Receptor | Total    |
|---------|----------|----------|
|         | 1        |          |
| U-238   |          |          |
| U-238   | 1.64E-02 | 1.64E-02 |
| U-235   |          |          |
| U-235   | 7.98E-04 | 7.98E-04 |
| U-234   |          |          |
| U-234   | 1.76E-02 | 1.76E-02 |
| PA-231  |          |          |
| PA-231  | 9.92E-02 | 9.92E-02 |
| TH-230  |          |          |
| TH-230  | 5.22E-01 | 5.22E-01 |
| AC-227  |          |          |
| AC-227  | 5.35E-01 | 5.35E-01 |
| RA-226  |          |          |
| RA-226  | 1.00E-01 | 1.00E-01 |
| PB-210  |          |          |
| PB-210  | 3.92E-02 | 3.92E-02 |

## ATTACHMENT 2

## ***Radiological Assessment of Grand Junction Quonset Hut Residual Contamination***

Decontamination efforts were performed on the exterior of the Quonset Hut in Grand Junction, CO to remove radioactive materials. Follow-up surveys indicate that some fixed contamination remains at levels above established total contamination limits. Based on previous characterization information, it is believed that the material is uranium mill tailings. The presence of both beta-gamma and alpha radiations indicates that the contamination is likely not a single radionuclide.

A radiological assessment was performed to determine potential doses to the public in the event of unrestricted release of the building. The risk assessment methodology employed here is based on the calculation of the number of hours required to receive a dose equal to the limits. The total effective dose equivalent (TEDE) was modeled using the RESRAD-BUILD code (version 2.10) developed by Argonne National Laboratories. Shallow dose to the skin was modeled using the VARSKIN Mod 2 code. A comparison was also made to applicable contamination limits.

The regulatory dose limits, contamination limits, and recommended dose limits that apply to this situation are taken from DOE Order 5400.5, Radiation Protection of the Public and Environment, and from recommendations of the ICRP and NCRP. The TEDE limit in DOE Order 5400.5 is 100 mrem per year. The Order further restricts the annual dose from airborne radioactivity to 10 mrem.

For unrestricted release of materials, the limits in Order 5400.5 are 1,000 dpm/100 cm<sup>2</sup> removable alpha, 1,000 dpm/100 cm<sup>2</sup> removable beta-gamma, 5,000 dpm/100 cm<sup>2</sup> total alpha (removable + fixed), and 5,000 dpm/100 cm<sup>2</sup> total beta-gamma (removable + fixed). The UMTRA Project has been instructed by DOE (Attachment 1) to use these contamination limits unless there is evidence that the majority of contamination is Ra-226 or Th-230, in which case more restrictive limits apply. Order 5400.5 also states that the average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm (0.4 in).

Although no shallow dose regulatory limit exists for members of the public, the ICRP (Publication 60) and the NCRP (Report 91) both recommend limiting shallow dose to the skin to 5,000 mrem per year for members of the public.

For all calculations, the maximum fixed beta-gamma measurement found on exterior surfaces less than approximately six foot above ground was used. This approach is conservative in that the maximum contamination level is considerably higher than the overall average for the building. It is appropriate because realistic exposure scenarios are best modeled using only accessible areas (less than six foot above ground). The maximum beta-gamma measurement was then correlated to specific radionuclide contamination levels using the tailings matrix alpha- and beta- factors from Attachment 2 (Reif 1992).

The highest fixed beta-gamma contamination level on the accessible exterior of the Quonset Hut is approximately 77,300 dpm/100 cm<sup>2</sup>. Many areas along the foundation of the north and south walls of the building are contaminated at levels ranging from 40,000 to 70,000 dpm/100 cm<sup>2</sup>.



Fixed alpha contamination is approximately 38,900 dpm/100 cm<sup>2</sup>. Note that the alpha and beta-gamma measurements were not necessarily taken in the same location. To determine the contamination level for a specific radionuclide (e.g., Th-234), the following formula is used:

$$\frac{77300 \text{ dpm}}{100 \text{ cm}^2} \times \frac{\text{pCi}}{2.22 \text{ dpm}} \times \frac{10^{-6} \text{ pCi}}{\text{pCi}} \times 1.93 \times 10^{-2} = 6.7 \times 10^{-6} \frac{\text{pCi}}{\text{cm}^2}$$

All radionuclide contamination levels were determined with this method, and the results in Attachment 3 were used in the subsequent models.

The RESRAD-BUILD model was conservative in that it was assumed that a person was exposed 1 foot from a large wall contaminated with the radionuclides in Attachment 3. It was also assumed that 50% of the contamination would be removed over the course of 10 years, and that all of the removed contamination would be available in the air. Attachment 4 contains the model input parameters and results. A summary of the risk assessment can be found in Attachment 5.

For shallow dose assessment, modeling methodology was conservative in that the maximum contamination level measured was assumed to be spread over a 5-m<sup>2</sup> area, with a target area of 100 cm<sup>2</sup>. Skin depth was estimated to be 7 mg/cm<sup>2</sup> for the shallow dose equivalent calculation. The separation of source and receptor was 304.8 mm (1 ft). The results from this analysis can be found in Attachment 3.

Based on the modeling assumptions and methodology, it can be seen that no annual dose limits or recommendations will be exceeded. These estimates are conservative in that reduction of the source term by weathering and radioactive decay over time is not considered. Table 1 gives the number of hours necessary in the exposure condition (1 foot from wall) for a given limit to be reached. Note that the average year contains 8,766 hours, and that nearly continuous exposure for a full year at one foot from the area of highest contamination would be required before the recommended skin dose limit was reached. Occupancy for this length of time would result in a dose that is one-third of the TEDE limit, and less than 3% of the airborne limit.

| Table 1. Quonset Hut Risk Assessment |      |                |
|--------------------------------------|------|----------------|
| Annual Limit                         | mrem | hours required |
| DOE 5400.5 TEDE                      | 100  | 21,000         |
| DOE 5400.5 Airborne                  | 10   | 302,000        |
| ICRP Skin (recommended)              | 5000 | 7,000          |

The existing maximum contamination levels on the Quonset Hut are compared to the unrestricted release criteria listed in DOE Order 5400.5 in Table 2. The maximum contamination level is fifteen times greater than the allowable residual contamination. Note that the calculated maximum shallow dose rate at 1 cm (0.4 in) is 2.2 mrad/h, greater than the 1.0 mrad/h recommended threshold in Order 5400.5.



To evaluate the dose from demolition of the Quonset Hut, the RESRAD-BUILD code was again used. Demolition model parameters were the same as used in the TEDE and inhalation dose calculation, except all of the contamination was assumed to become airborne over the course of two days. The demolition TEDE was calculated as 6.1 mrem, with inhalation the main pathway (Attachment 6).

| <i>Table 2. Comparison of Existing Contamination Levels to Unrestricted Release Criteria</i> |                  |              |                                                                                          |              |
|----------------------------------------------------------------------------------------------|------------------|--------------|------------------------------------------------------------------------------------------|--------------|
| <i>Quonset Hut</i><br>(max dpm/100 cm <sup>2</sup> )                                         |                  |              | <i>DOE Order 5400.5</i><br><i>Allowable Contamination*</i><br>(dpm/100 cm <sup>2</sup> ) |              |
|                                                                                              | <i>Removable</i> | <i>Fixed</i> | <i>Removable</i>                                                                         | <i>Total</i> |
| <i>alpha</i>                                                                                 | 25               | 38,900       | 1000                                                                                     | 5000         |
| <i>beta-gamma</i>                                                                            | N/A              | 77,300       | 1000                                                                                     | 5000         |
| * Contamination limits for uranium and its associated decay products<br>N/A = Not Available  |                  |              |                                                                                          |              |

#### Key Points:

- The contamination levels on the Quonset Hut exceed the allowable contamination levels for unrestricted release found in DOE Order 5400.5.
- The recommended dose rate limit for surface contamination contained in Order 5400.5 is exceeded.
- Based on modeling, no member of the public could receive doses that approach regulatory or recommended limits.
- Demolition of the building does not appear to pose a radiological concern.
- The Quonset Hut is currently used for equipment storage and is fenced. A city park is to be built in the vicinity of the Quonset Hut.

#### References

Reif, R.H.; Turner, J.B.; Carlson, D.S. Uranium in vitro bioassay action level used to screen workers for chronic inhalation intakes of uranium mill tailings. Health Phys. 63:398-401; 1992.

Department of Energy

MK-FERGUSON CO. Albuquerque Field Office  
 ALBUQUERQUE UMTRA Project Office

JAN 22 1992

RECEIVED

to: James G. Oldham, Project Director, MK-F

Should you have any questions, please contact Charlene Esparza-Baca at 845-5664.

*Frank D. Bosiljevac*  
Frank D. Bosiljevac  
Technical Support Group Leader  
Uranium Mill Tailings Remedial  
Action Project Office

cc:  
C. Soden, SPD, AL  
F. Sprague, FPD, AL

[illegible]

## ATTACHMENT 2

| tailings<br>matrix | Bq / unit<br>tailings | beta | alpha | beta-Bq<br>/unit | alpha-Bq<br>/unit | beta<br>factor* | alpha<br>factor** |
|--------------------|-----------------------|------|-------|------------------|-------------------|-----------------|-------------------|
| U-238              | 0.083                 |      | 1     |                  | 8.30E-02          |                 | 1.29E-02          |
| Th-234             | 0.083                 | 1    |       | 8.30E-02         |                   | 1.93E-02        |                   |
| Pa-234             | 0.083                 | 1    |       | 8.30E-02         |                   | 1.93E-02        |                   |
| U-234              | 0.083                 |      | 1     |                  | 8.30E-02          |                 | 1.29E-02          |
| Th-230             | 1                     |      | 1     |                  | 1.00E+00          |                 | 1.55E-01          |
| Ra-226             | 1                     |      | 1     |                  | 1.00E+00          |                 | 1.55E-01          |
| Rn-222             | 1                     |      | 1     |                  | 1.00E+00          |                 | 1.55E-01          |
| Po-218             | 1                     |      | 1     |                  | 1.00E+00          |                 | 1.55E-01          |
| Pb-214             | 1                     | 1    |       | 1.00E+00         |                   | 2.32E-01        |                   |
| Bi-214             | 1                     | 1    |       | 1.00E+00         |                   | 2.32E-01        |                   |
| Po-214             | 1                     |      | 1     |                  | 1.00E+00          |                 | 1.55E-01          |
| Pb-210             | 1                     | 1    |       | 1.00E+00         |                   | 2.32E-01        |                   |
| Bi-210             | 1                     | 1    |       | 1.00E+00         |                   | 2.32E-01        |                   |
| Po-210             | 1                     |      | 1     |                  | 1.00E+00          |                 | 1.55E-01          |
| U-235              | 0.003868              |      | 1     |                  | 3.87E-03          |                 | 6.00E-04          |
| Th-231             | 0.003868              | 1    |       | 3.87E-03         |                   | 8.97E-04        |                   |
| Pa-231             | 0.0466                |      | 1     |                  | 4.66E-02          |                 | 7.23E-03          |
| Ac-227             | 0.0466                | 1    |       | 4.66E-02         |                   | 1.08E-02        |                   |
| Th-227             | 0.0466                |      | 1     |                  | 4.66E-02          |                 | 7.23E-03          |
| Ra-223             | 0.0466                |      | 1     |                  | 4.66E-02          |                 | 7.23E-03          |
| Rn-219             | 0.0466                |      | 1     |                  | 4.66E-02          |                 | 7.23E-03          |
| Po-215             | 0.0466                |      | 1     |                  | 4.66E-02          |                 | 7.23E-03          |
| Pb-211             | 0.0466                | 1    |       | 4.66E-02         |                   | 1.08E-02        |                   |
| Bi-211             | 0.0466                |      | 1     |                  | 4.66E-02          |                 | 7.23E-03          |
| Tl-207             | 0.0466                | 1    |       | 4.66E-02         |                   | 1.08E-02        |                   |
| sum                | 10.759                | 10   | 15    | 4.310            | 6.449             |                 |                   |

\* fraction of beta-Bq per unit tailings divided by total beta-Bq

\*\* fraction of alpha-Bq per unit tailings divided by total alpha-Bq

Quonset

77300 dpm/100cm<sup>2</sup> beta  
3.48E-04  $\mu\text{Ci}/\text{cm}^2$ 38900 dpm/100cm<sup>2</sup> alpha  
1.75E-04  $\mu\text{Ci}/\text{cm}^2$ VARSKIN Mod2  
source area = 5 m<sup>2</sup>

|        | beta<br>$\mu\text{Ci}/\text{cm}^2$ | alpha<br>$\mu\text{Ci}/\text{cm}^2$ | @1ft<br>rad/h | @1cm<br>rad/h |
|--------|------------------------------------|-------------------------------------|---------------|---------------|
| U-238  |                                    | 2.26E-06                            |               |               |
| Th-234 | 6.71E-06                           |                                     | 0.00E+00      | 7.13E-06      |
| Pa-234 | 6.71E-06                           |                                     | 3.02E-05      | 6.01E-05      |
| U-234  |                                    | 2.26E-06                            |               |               |
| Th-230 |                                    | 2.72E-05                            |               |               |
| Ra-226 |                                    | 2.72E-05                            |               |               |
| Rn-222 |                                    | 2.72E-05                            |               |               |
| Po-218 |                                    | 2.72E-05                            |               |               |
| Pb-214 | 8.08E-05                           |                                     | 1.59E-04      | 8.68E-04      |
| Bi-214 | 8.08E-05                           |                                     | 2.81E-04      | 6.39E-04      |
| Po-214 |                                    | 2.72E-05                            |               |               |
| Pb-210 | 8.08E-05                           |                                     | 0.00E+00      | 0.00E+00      |
| Bi-210 | 8.08E-05                           |                                     | 2.28E-04      | 6.14E-04      |
| Po-210 |                                    | 2.72E-05                            |               |               |
| U-235  |                                    | 1.05E-07                            |               |               |
| Th-231 | 3.12E-07                           |                                     | 0.00E+00      | 2.95E-06      |
| Pa-231 |                                    | 1.27E-06                            |               |               |
| Ac-227 | 3.77E-06                           |                                     |               |               |
| Th-227 |                                    | 1.27E-06                            |               |               |
| Ra-223 |                                    | 1.27E-06                            |               |               |
| Rn-219 |                                    | 1.27E-06                            |               |               |
| Po-215 |                                    | 1.27E-06                            |               |               |
| Pb-211 | 3.77E-06                           |                                     |               |               |
| Bi-211 |                                    | 1.27E-06                            |               |               |
| Tl-207 | 3.77E-06                           |                                     |               |               |

sum

6.98E-04 rad/h

2.19E+00 mrad/h

ICRP 60 recommended skin  
dose limit to public:

5 rem

time to reach limit:

7000 hours

\*\* RESRAD-BUILD Program Output, Version 2.10 11/07/96 12:36 Page: 0- 0 : 1 \*\*

Title : Default Case for RESRAD-BUILD

Input File : QUONSET.DAT

```

=====
=====
eee                                     eee
eee   RESRAD-BUILD Table of Contents   eee
eee                                     eee
=====
=====

```

```

Input Parameters..... 0-1
For Each Time (I) :.....
  Time Specific Parameters..... 1-1
  Receptor-Source Dose Summary..... 1-2
  Dose by Pathway Detail..... 1-3
  Dose by Nuclide Detail..... 1-4
Full Summary..... F-1

```

RESRAD-BUILD Input Parameters

Number of Sources : 1  
Number of Receptors: 1  
Total Time : 3.650000E+02 days  
Fraction Inside : 1.000000E+00

Receptor Information

| Receptor | Room | x<br>[m] | y<br>[m] | z<br>[m] | FracTime | Inhalation<br>[m3/day] | Ingestion(Dust)<br>[m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1        | 1    | 22.860   | 45.415   | 1.800    | 1.000    | 1.80E+01               | 1.00E-04                   |

Receptor-Source Relationship

| Recept               | Source   | 1           |
|----------------------|----------|-------------|
| Density Thickness Or |          |             |
| [g/cm3] [cm]         |          |             |
| 1                    | 2.40E+00 | 0.00E+00 RT |

Building Information

Building Air Exchange Rate: 1.00E+02 1/hr

| Height[m] | Air Exchanges [m3/hr] |                 |
|-----------|-----------------------|-----------------|
| Area [m2] |                       |                 |
|           | *****                 |                 |
|           | *                     | *               |
|           | *                     | *               |
|           | *                     | <=Q01: 2.06E+07 |
| H1: 9.144 | Room 1                | Q10 : 2.06E+07  |
|           | LAMBDA: 1.00E+02      |                 |
| Area***** | *                     | *               |
|           | *                     | *               |
|           | *****                 |                 |

Deposition velocity: 1.00E-02 [m/s]    Resuspension Rate: 5.00E-06 [1/s]



Source Information

Source: 1  
Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57[m]  
Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y  
Pathway ::  
Direct Ingestion Rate: 0.000E+00 [1/hr]  
Fraction released to air: 1.000E+00  
Removable fraction: 5.000E-01  
Time to Remove: 3.650E+03 [day]  
  
Radon Release Fraction: 1.000E-01

Contamination::

| Nuclide Concentration |            | Dose Conversion Factors                           |                        |                        |                        |           |
|-----------------------|------------|---------------------------------------------------|------------------------|------------------------|------------------------|-----------|
|                       |            | Ingestion Inhalation External External Submersion |                        |                        |                        |           |
|                       |            | (Surface) (Volume)                                |                        |                        |                        |           |
| [pCi/m2]              | [mrem/pCi] | [mrem/pCi]                                        | [mrem/yr/<br>(pCi/m2)] | [mrem/yr/<br>(pCi/m3)] | [mrem/yr/<br>(pCi/m3)] |           |
| U-238                 | 2.260E+04  | 2.500E-04                                         | 1.200E-01              | 3.530E-06              | 9.510E-08              | 1.600E-04 |
| U-235                 | 1.050E+03  | 2.500E-04                                         | 1.200E-01              | 1.950E-05              | 4.740E-07              | 9.030E-04 |
| U-234                 | 2.260E+04  | 2.600E-04                                         | 1.300E-01              | 8.750E-08              | 2.520E-10              | 8.930E-07 |
| PA-231                | 1.270E+04  | 1.100E-02                                         | 1.300E+00              | 4.760E-06              | 1.190E-07              | 2.010E-04 |
| TH-230                | 2.720E+05  | 5.300E-04                                         | 3.200E-01              | 8.780E-08              | 7.570E-10              | 2.040E-06 |
| AC-227                | 3.770E+04  | 1.500E-02                                         | 6.700E+00              | 4.530E-05              | 1.260E-06              | 2.160E-03 |
| RA-226                | 2.720E+05  | 1.100E-03                                         | 7.900E-03              | 1.940E-04              | 7.000E-06              | 1.040E-02 |
| PB-210                | 8.080E+05  | 6.700E-03                                         | 2.100E-02              | 4.140E-07              | 3.820E-09              | 1.430E-05 |



Assessment for Time: 1  
Time =0.00E+00 yr

Source Information

Source: 1  
Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57 [m]  
Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y  
Pathway ::  
Direct Ingestion Rate: 0.000E+00 [1/hr]  
Fraction released to air: 1.000E+00  
Removable fraction: 5.000E-01  
Time to Remove: 3.650E+03 [day]

| Contamination:: | Nuclide | Concentration<br>[pCi/m2] |
|-----------------|---------|---------------------------|
|                 | U-238   | 2.260E+04                 |
|                 | U-235   | 1.050E+03                 |
|                 | U-234   | 2.260E+04                 |
|                 | PA-231  | 1.270E+04                 |
|                 | TH-230  | 2.720E+05                 |
|                 | AC-227  | 3.770E+04                 |
|                 | RA-226  | 2.720E+05                 |
|                 | PB-210  | 8.080E+05                 |

RESRAD-BUILD Dose Tables

Receptor Point-Source Doses  
[mrem]

|            | Source  | Total   |
|------------|---------|---------|
|            | 1       |         |
| Receptor 1 | 4.3E+01 | 4.3E+01 |
| Total      | 4.3E+01 | 4.3E+01 |

Pathway Detail of Doses  
=====

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 4.23E+01 | 1.11E-05   | 3.40E-07  | 2.90E-01   | 1.48E-05 | 1.34E-03  |
| Total    | 4.23E+01 | 1.11E-05   | 3.40E-07  | 2.90E-01   | 1.48E-05 | 1.34E-03  |

Title : Default Case for RESRAD-BUILD

Input File : QUONSET.DAT      Evaluation Time:    1.00000    years

Pathway Detail of Doses  
=====

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 4.01E+01 | 1.11E-05   | 3.40E-07  | 2.86E-01   | 1.41E-05 | 1.31E-03  |
| Total    | 4.01E+01 | 1.11E-05   | 3.40E-07  | 2.86E-01   | 1.41E-05 | 1.31E-03  |

Title : Default Case for RESRAD-BUILD

Input File : QUONSET.DAT      Evaluation Time:    2.00000    years

Pathway Detail of Doses

eeeeeeeeeeeeeeeeeeeeeeeeeeeeeeee

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 3.80E+01 | 1.11E-05   | 3.40E-07  | 2.82E-01   | 1.33E-05 | 1.29E-03  |
| Total    | 3.80E+01 | 1.11E-05   | 3.40E-07  | 2.82E-01   | 1.33E-05 | 1.29E-03  |

Pathway Detail of Doses  
eeeeeeeeeeeeeeeeeeeeeeeeeeee  
[mrem]

|           |          |            |           |            |          |           |
|-----------|----------|------------|-----------|------------|----------|-----------|
| Source: 1 |          |            |           |            |          |           |
| Receptor  | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
| 1         | 3.37E+01 | 1.11E-05   | 3.39E-07  | 2.74E-01   | 1.18E-05 | 1.24E-03  |
| Total     | 3.37E+01 | 1.11E-05   | 3.39E-07  | 2.74E-01   | 1.18E-05 | 1.24E-03  |

\*\* RESRAD-BUILD Program Output, Version 2.10 11/07/96 12:37 Page: 5- 3 : 23 \*\*

Title : Default Case for RESRAD-BUILD

Input File : QUONSET.DAT      Evaluation Time:      6.00000      years

Pathway Detail of Doses

\*\*\*\*\*

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 2.94E+01 | 1.11E-05   | 3.39E-07  | 2.67E-01   | 1.04E-05 | 1.20E-03  |
| Total    | 2.94E+01 | 1.11E-05   | 3.39E-07  | 2.67E-01   | 1.04E-05 | 1.20E-03  |

Title : Default Case for RESRAD-BUILD

Input File : QUONSET.DAT      Evaluation Time:      8.00000      years

Pathway Detail of Doses

=====

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 2.52E+01 | 1.10E-05   | 3.39E-07  | 2.60E-01   | 8.87E-06 | 1.16E-03  |
| Total    | 2.52E+01 | 1.10E-05   | 3.39E-07  | 2.60E-01   | 8.87E-06 | 1.16E-03  |



Title : Default Case for RESRAD-BUILD

Input File : QUONSET.DAT      Evaluation Time:    10.0000    years

Pathway Detail of Doses

#####

[mrem]

Source: 1

| Receptor | External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|----------|------------|-----------|------------|----------|-----------|
| 1        | 2.10E+01 | 0.00E+00   | 0.00E+00  | 0.00E+00   | 7.40E-06 | 0.00E+00  |
| Total    | 2.10E+01 | 0.00E+00   | 0.00E+00  | 0.00E+00   | 7.40E-06 | 0.00E+00  |

## RESRAD-BUILD 2.10

Quonset Hut

Pathway Detail of Doses at  $t = 0$  (mrem)

| External | Deposition | Immersion | Inhalation | Radon    | Ingestion |
|----------|------------|-----------|------------|----------|-----------|
| 4.23E+01 | 1.11E-05   | 3.40E-07  | 2.90E-01   | 1.48E-05 | 1.34E-03  |

All Pathways Combined:

4.26E+01 mrem  
4.86E-03 mrem/h

limit: 100 mrem

time to reach limit: 21000 hours

Inhalation Pathway:

2.90E-01 mrem  
3.31E-05 mrem/h

limit: 10 mrem

time to reach limit: 302000 hours

\*\* RESRAD-BUILD Program Output, Version 2.10 11/11/96 11:06 Page: 0- 0 : 1 \*\*  
Title : Default Case for RESRAD-BUILD  
Input File : QUONDEMO.DAT

```

#####
#####
eee                                     eee
eee   RESRAD-BUILD Table of Contents   eee
eee                                     eee
#####
#####

```

```

Input Parameters..... 0-1
For Each Time (I) :.....
  Time Specific Parameters..... 1-1
  Receptor-Source Dose Summary..... 1-2
  Dose by Pathway Detail..... 1-3
  Dose by Nuclide Detail..... 1-4
Full Summary..... F-1

```

\*\* RESRAD-BUILD Program Output, Version 2.10 11/11/96 11:06 Page: 0- 1 : 2 \*\*  
 Title : Default Case for RESRAD-BUILD  
 Input File : QUONDEMO.DAT

```

#####
#####
eee                                     eee
eee   RESRAD-BUILD Input Parameters   eee
eee                                     eee
#####
#####
  
```

Number of Sources : 1  
 Number of Receptors: 1  
 Total Time : 2.000000E+00 days  
 Fraction Inside : 1.000000E+00

##### Receptor Information #####

| Receptor | Room | x<br>[m] | y<br>[m] | z<br>[m] | FracTime | Inhalation<br>[m3/day] | Ingestion(Dust)<br>[m2/hr] |
|----------|------|----------|----------|----------|----------|------------------------|----------------------------|
| 1        | 1    | 22.860   | 45.415   | 1.800    | 1.000    | 1.80E+01               | 1.00E-04                   |

##### Receptor-Source Relationship #####

| Recept                               | Source   | 1           |
|--------------------------------------|----------|-------------|
| Density Thickness Or<br>[g/cm3] [cm] |          |             |
| 1                                    | 2.40E+00 | 0.00E+00 RT |

~~~~~ Building Information ~~~~~

Building Air Exchange Rate: 1.00E+02 1/hr

| Height[m] | Air Exchanges [m3/hr] | |
|-----------|-----------------------|-----------------|
| Area [m2] | | |
| | ***** | |
| | * | * |
| | * | * |
| | * | <=Q01: 2.06E+07 |
| h1: 9.144 | Room 1 | Q10 : 2.06E+07 |
| | LAMBDA: 1.00E+02 | * |
| Area***** | * | * |
| | * | * |
| | ***** | |

Deposition velocity: 1.00E-02 [m/s] Resuspension Rate: 5.00E-06 [1/s]

Source Information

Source: 1

Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57[m]
Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y
Pathway ::
Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 1.000E+00
Removable fraction: 1.000E+00
Time to Remove: 2.000E+00 [day]

Radon Release Fraction: 1.000E-01

Contamination::

| Nuclide Concentration | Dose Conversion Factors | | | | | |
|-----------------------|-------------------------|------------|------------------------|------------------------|------------------------|-----------|
| | Ingestion | Inhalation | External | External | Submersion | |
| | | | (Surface) | (Volume) | | |
| [pCi/m2] | [mrem/pCi] | [mrem/pCi] | [mrem/yr/
(pCi/m2)] | [mrem/yr/
(pCi/m3)] | [mrem/yr/
(pCi/m3)] | |
| U-238 | 2.260E+04 | 2.500E-04 | 1.200E-01 | 3.530E-06 | 9.510E-08 | 1.600E-04 |
| U-235 | 1.050E+03 | 2.500E-04 | 1.200E-01 | 1.950E-05 | 4.740E-07 | 9.030E-04 |
| U-234 | 2.260E+04 | 2.600E-04 | 1.300E-01 | 8.750E-08 | 2.520E-10 | 8.930E-07 |
| PA-231 | 1.270E+04 | 1.100E-02 | 1.300E+00 | 4.760E-06 | 1.190E-07 | 2.010E-04 |
| TH-230 | 2.720E+05 | 5.300E-04 | 3.200E-01 | 8.780E-08 | 7.570E-10 | 2.040E-06 |
| AC-227 | 3.770E+04 | 1.500E-02 | 6.700E+00 | 4.530E-05 | 1.260E-06 | 2.160E-03 |
| RA-226 | 2.720E+05 | 1.100E-03 | 7.900E-03 | 1.940E-04 | 7.000E-06 | 1.040E-02 |
| PB-210 | 8.080E+05 | 6.700E-03 | 2.100E-02 | 4.140E-07 | 3.820E-09 | 1.430E-05 |

Title : Default Case for RESRAD-BUILD

input File : QUONDEMO.DAT Evaluation Time: 0.000000 years

Assessment for Time: 1
Time =0.00E+00 yr

#####

Source Information

Source: 1

Location:: Room : 1 x: 22.86 y: 45.72 z: 4.57 [m]
Geometry:: Type: Area Area:4.18E+02 [m2] Direction: y
Pathway ::

Direct Ingestion Rate: 0.000E+00 [1/hr]
Fraction released to air: 1.000E+00
Removable fraction: 1.000E+00
Time to Remove: 2.000E+00 [day]

| Contamination:: | Nuclide | Concentration
[pCi/m2] |
|-----------------|---------|---------------------------|
| | U-238 | 2.260E+04 |
| | U-235 | 1.050E+03 |
| | U-234 | 2.260E+04 |
| | PA-231 | 1.270E+04 |
| | TH-230 | 2.720E+05 |
| | AC-227 | 3.770E+04 |
| | RA-226 | 2.720E+05 |
| | PS-210 | 8.080E+05 |

RESRAD-BUILD Dose Tables

Receptor Point-Source Doses
[mrem]

| | Source | Total |
|------------|---------|---------|
| | 1 | |
| Receptor 1 | 6.1E+00 | 6.1E+00 |
| Total | 6.1E+00 | 6.1E+00 |

Title : Default Case for RESRAD-BUILD

Input File : QUONDEMO.DAT Evaluation Time: 0.000000 years

Pathway Detail of Doses
eeeeeeeeeeeeeeeeeeeeeeeeeeee
[mrem]

| | | | | | | | |
|-----------|----------|------------|-----------|------------|----------|-----------|--|
| Source: 1 | | | | | | | |
| Receptor | External | Deposition | Immersion | Inhalation | Radon | Ingestion | |
| 1 | 2.32E-01 | 2.22E-04 | 6.80E-06 | 5.81E+00 | 8.12E-08 | 2.67E-02 | |
| Total | 2.32E-01 | 2.22E-04 | 6.80E-06 | 5.81E+00 | 8.12E-08 | 2.67E-02 | |

Title : Default Case for RESRAD-BUILD

Input File : QUONDEMO.DAT Evaluation Time: 0.000000 years

Nuclide Detail of Doses

oooooooooooooooooooo

[mrem]

Source: 1

| Nuclide | Receptor | Total |
|---------|----------|----------|
| | 1 | |
| U-238 | | |
| U-238 | 4.17E-02 | 4.17E-02 |
| U-235 | | |
| U-235 | 2.02E-03 | 2.02E-03 |
| U-234 | | |
| U-234 | 4.48E-02 | 4.48E-02 |
| PA-231 | | |
| PA-231 | 2.52E-01 | 2.52E-01 |
| TH-230 | | |
| TH-230 | 1.33E+00 | 1.33E+00 |
| AC-227 | | |
| AC-227 | 3.86E+00 | 3.86E+00 |
| RA-226 | | |
| RA-226 | 2.55E-01 | 2.55E-01 |
| PB-210 | | |
| PB-210 | 2.83E-01 | 2.83E-01 |

eee RESRAD-BUILD Dose (Time) Tables eee
eee

#####

Receptor Doses By Time

[mrem]

Time [yr]

0.00E+00
1 6.07E+00

Receptor Doses Per Year

[mrem/yr]

Time [yr]

0.00E+00
1 1.11E+03