Review of Appendix BB, Revision 1 – General Steel Industries

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LIST OF FINDINGS

Finding 1 **Neutron Dose Rates:** Effective dose incompatible with OCAS-IG-001

Finding 2 **Beta Skin Dose—**Beta doses to the skin of the betatron operator lower than SC&A's

Finding 3 **No Dedicated Radiographic Facility in No. 6 Building Prior to 1955:** Mode of triangular distribution needs to be increased since radiographers were in an unshielded location

Finding 4 **Maximum of Triangular Distribution of Photon Exposures for 1961 Should Be 12 R/y**

Finding 5 **Combined Exposures to ^{226}Ra and Betatron Operations During 1952–1962**

Finding 6 **Beta Skin Dose to Layout Man Significantly Lower than Those Calculated by SC&A**

Finding 7 **Uranium Inhalation From Metal Handling in 1966:** Intake during first 6 months of 1966 is understated by a factor of 2.

Finding 8 **Ingestion Intakes Not Consistent with OCAS-TIB-009**

Finding 9 **Ingestion Intakes During Residual Period Inconsistent with Operational Period**

Finding 10 **External Exposure of Betatron Operator (New Finding):** Effective dose incompatible with OCAS-IG-001

RESOLUTION OF FINDINGS

Finding 1: DCAS agreed to revise the neutron dose calculations to use either ambient dose equivalent or deep dose equivalent conversions.

Finding 2: DCAS disagreed with SC&A beta skin dose to the betatron operator, intends to recalculate the using a new model**.**

Finding 3: DCAS intends to revise mode of triangular distribution to reflect radiographer's photon dose at 2 mR/h exclusion boundary during radiographic exposures during 1952–1955.

Finding 4: DCAS intends to revise maximum of triangular distribution of photon exposures for 1961 to 12 R/y**.**

Finding 5: DCAS disagreed with SC&A's finding that radiographer using ^{226}Ra could also have worked on betatron.

Finding 6: DCAS disagreed with SC&A beta skin dose to the layout man, proposed revised doses based on a new model.

Finding 7: DCAS agreed to correct inhaled uranium intakes during first 6 months of 1966.

Finding 8: DCAS agreed to revise ingested uranium intakes during operational period, based on average annual airborne uranium concentrations during year of peak concentrations.

Finding 9: DCAS agreed to revise ingested uranium intakes during residual period, based on ingested intakes at end of operational period.

Finding 10: DCAS has not yet responded to this new finding.

DETAILED DISCUSSION OF UNRESOLVED FINDINGS

- **Beta skin dose**
  - **Betatron operators—Finding 2**
    - Unresolved differences between SC&A and NIOSH values

Annual Doses to Skin of Betatron Operators from Beta Radiation (rads)

Year	Hands and forearms			Other skin		
	SC&A	NIOSH[a]	Δ	SC&A	NIOSH[a]	Δ
1952-1957	35.29	36.74	4%	4.32	3.87	-10%
1958	30.20	31.31	4%	4.05	3.56	-12%
1959-1960	28.10	29.07	3%	3.94	3.43	-13%
1961	31.69	32.91	4%	4.13	3.65	-12%
1962	24.06	24.76	3%	3.72	3.19	-14%
1963	9.35	9.06	-3%	2.94	2.3	-22%
1964	5.87	5.35	-9%	2.75	2.09	-24%
1965	5.32	4.76	-10%	2.72	2.06	-24%
1966[b]	2.38	2.09	-12%	1.35	1.01	-25%

[a] Appendix BB, Rev. 1

[b] During contract period January 1–June 30

    - NIOSH to revise beta skin dose to betatron operators using new model—results not yet available

- **Layout man—Finding 6**
  - Unresolved differences between SC&A and NIOSH values

Annual Doses to Skin of Layout Man from Beta Rays Emitted by Irradiated Steel

Skin on:	Dose (rad/y)		
	SC&A	NIOSH	
		2014[a]	2015[b]
Hands and forearms	1.89	0.807	0.264
Rest of body	1.14	0.463	0.147

[a] Appendix BB, Rev. 1

[b] NIOSH Response Paper

- **Radiographer may have been exposed to both ^{226}Ra and betatron—Finding 5**
  - Reason for finding: NIOSH assigned zero doses from neutrons and beta rays to plant workers during 1952–1962
  - Technical basis:
    - GSI application for AEC byproduct materials license: "A maximum of 30% of each shift is used for actual exposure" (using ^{226}Ra).
    - Radiographer could have worked with ^{226}Ra sources and have still spent up to 70% of his shift in the Old Betatron Building radiographing uranium and steel
    - Interview with former GSI radiographer from Radium Era
      - Did both radium and betatron radiography— perhaps 50–60% of the time using the betatron, the remainder using radium
      - Only worked weekends: 40–90 shifts/y
      - Recorded dose 2.02 R/y—extrapolated dose to full-time radiographer: 9.1–20.5 R/y
      - Consistent with triangular distribution: 6.279–9.69–12 or 15 R/y during 1957–1961
  - Conclusion: Radiographer's assumed exposure to both ^{226}Ra and betatron is plausible and claimant favorable

- Result:
  - No change in photon dose

Beta Skin Doses and Neutron Doses to Radiographers During Radium Era

Year	Beta skin dose (rads/y)		Neutron H*(10) (rem/y)
	Hands & forearms	Rest of body	
1952-1957	34.13	3.53	0.320
1958	29.04	3.25	0.308
1959-1960	26.95	3.14	0.303
1961	30.54	3.33	0.311
1962	22.90	2.93	0.293

Note: Adjusted for 70% of work hours devoted to betatron radiography

- **Assumed residual photon radiation from betatron after shutdown expressed as effective dose—incompatible with the dose conversion factors listed in OCAS-IG-001 (Finding 10—new)**

Estimated Maximum Weekly Air Kerma Dose to Betatron Operators

Photon Energy (keV)	Dose Coefficients for PA geometry Breast (Gy/Gy)	Maximum weekly air kerma (mrad)
30	0.0489	204
40	0.181	55
50	0.328	30
60	0.439	23
70	0.511	20
80	0.545	18
100	0.574	17
150	0.6	17
200	0.625	16
300	0.663	15
400	0.693	14
500	0.717	14
600	0.737	14
800	0.767	13
1,000	0.791	13
2,000	0.863	12
4,000	0.905	11
6,000	0.911	11
8,000	0.911	11
10,000	0.911	11

Note: Based on an assumed dose to female breast (surrogate for film badge) of 10 mrem/week

  - Recommend using 204 mrad/week (10.2 rad/y) air kerma with maximum DCF for 30 keV photons