Comparison of Updated NIOSH and SC&A Exposure Assessments at GSI

Robert Anigstein

S. Cohen & Associates

April 26, 2013

PERIODS OF SITE OPERATIONS, DIVIDED ACCORDING TO LIMITING EXPOSURE SCENARIOS

- January 1, 1953: Start of covered operations under EEOICPA
  - Two 500-mCi ^{226}Ra sources used for radiography, in addition to 24-MeV betatron ("Old Betatron")
- May 21, 1962: GSI acquires two ^{60}Co sources (260 and 280 mCi) to replace ^{226}Ra
- October 1, 1963: Assumed date "New Betatron" began operation at Commonwealth foundry in Granite City; Old Betatron upgraded to 25 MeV
- June 30, 1966: End date of last MCW purchase order—beginning of residual period

BOUNDING SOURCES OF EXTERNAL RADIATION EXPOSURE AT GSI
(Entire period of AEC operations, unless otherwise noted)

- Exposure to sealed radiography sources
  - ^{226}Ra—2 sources, 500 mCi ea: 1953–May 21, 1962
- Exposure to direct penetrating radiation (photons + neutrons) from betatron operations
  - Stray radiation during betatron operation
  - Delayed radiation from activated metals
- Exposure of skin to non-penetrating (beta) radiation
  - Natural uranium and photoactivated uranium isotopes
  - Activated steel

BOUNDING ANNUAL EXPOSURES TO PENETRATING (PHOTON) RADIATION
(Operational Period)

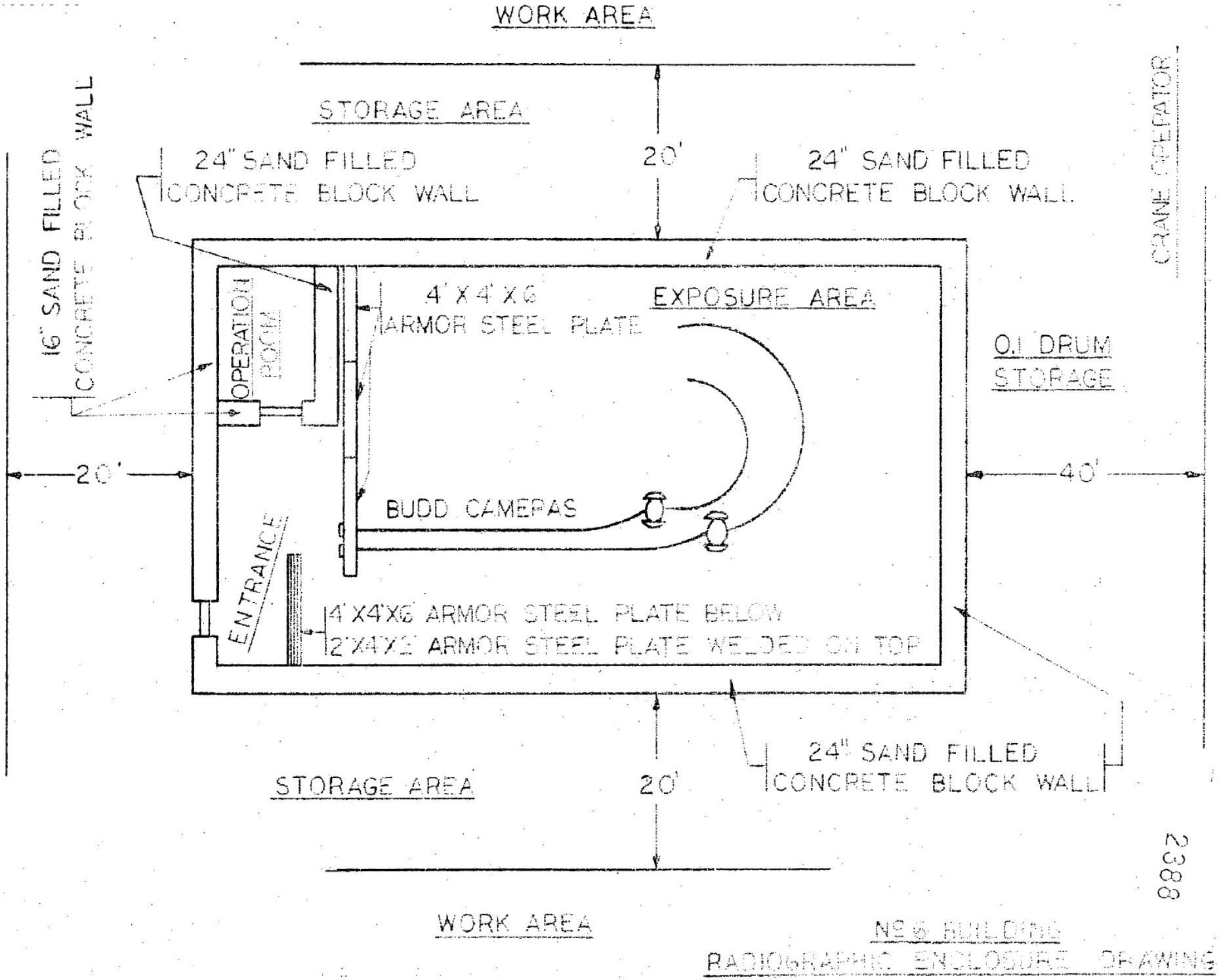
Years	SC&A—applied to all employees		NIOSH		
	Bounding scenario	Dose/exposure	Source	Radiographers	Others
1953–1960†	Radiographer using Ra-226	6.279–9.69–15 rem*	Ra-226	6.279–9.69–15 rem*	0.868 R
1961–1962†		6.279–9.69–12 rem*		6.279–9.69–12 rem*	
9/30/63–6/30/66	Layout man	9.2 R	Betatron	4.483 R	

† Revised dates, based on date of revised AEC rule, pending concurrence by work group and NIOSH

* Triangular distribution–as per W-G meeting 2/21/2013

Basis for Disagreement Between SC&A and NIOSH: Doses to Nonradiographers During Radium Era

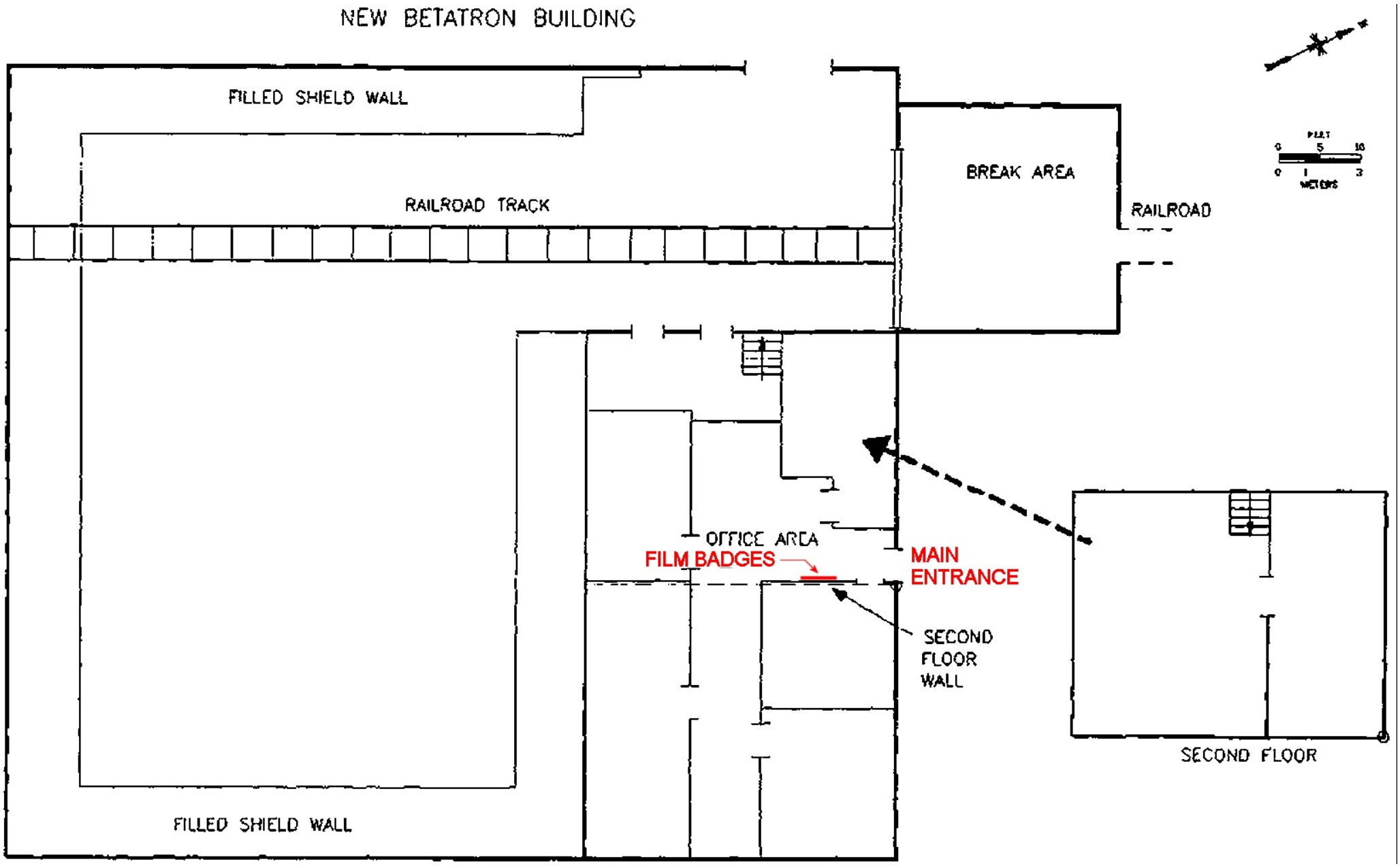
- NIOSH scenario based on radiation protection survey of No. 6 Building radiographic facility using ^{60}Co sources not applicable to operating conditions
    - Doses calculated for areas not normally accessible/occupied by non radiographers
    - Facility built in 1955 (according to information supplied by copetitioner)—not applicable before that
- Insufficient knowledge about practices during Radium Era to assure no incidents or unusual exposures
- No knowledge of practices before 1956
- Documented loss/theft of radium source in 1953
- Radiography using sealed sources notorious for excessive exposures
- Known safety concerns over fishpole technique caused State of Illinois to ban practice
- Account of exposures of two unmonitored nonradiographers in betatron shooting room—other incidents cannot be precluded due to absence of records



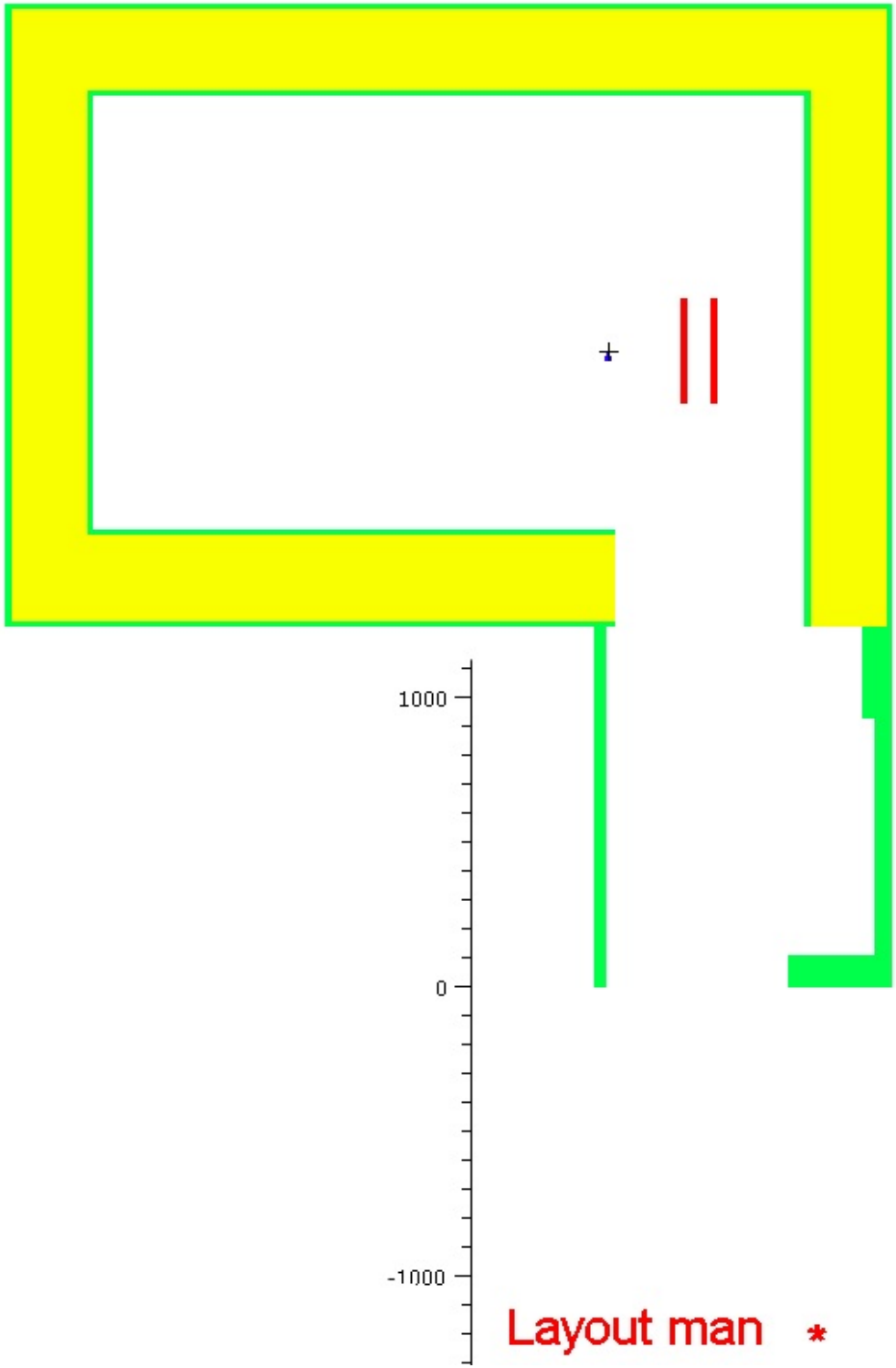
Radiographic Facility in No. 6 Bldg.

Basis for Disagreement Between SC&A and NIOSH: Doses to Layout Man During New Betatron Era

- NIOSH used 15 betatron scenarios
  - 45º angle to axis not consistent with industrial radiography
  - Arbitrary selection of betatron positions and orientations
  - Normalized to 10 mR/week at film-badge storage rack
    - Shielding by outer wall of control room understated due to low density of concrete blocks
    - No shielding by interior walls or equipment
    - Landauer zeroed control badge (No. 000)—doses reported only if
      - >50 mrem ***or***
      - >½ of worker badges
    - No information on Badge No. 1: "BETATRON CTL"—may have been in Old Betatron Building (location of supervisor's office)
  - Location of layout man on RR track unrealistic and not claimant favorable
  - SC&A scenario leads to reasonable upper-bound exposures
- NIOSH included heavy steel door (0.85 in)
  - Workers described ribbon door, made of thin sheet metal
- NIOSH used SC&A 2008 MCNPX version 26e results for beta dose
  - Current version of MCNPX shows increased production of beta-emitting nuclides in steel



Floor Plan of New Betatron Building, Showing Location of Rack for Storing Film Badges



SC&A Model of Exposure Geometry of Layout Man

BOUNDING SCENARIOS FOR NEUTRON AND BETA EXPOSURES

Apply to All Employees

Year	Neutron dose (rem/y)		β dose to skin—betatron operator (rads/y)			
	SC&A Betatron operator	NIOSH Layout man	Hands & forearms		Other skin	
			SC&A	NIOSH	SC&A	NIOSH
1953-1957	0.48	0.148	33.4	25.9	6.27	2.27
1958	0.48		32.1	25.9	6.22	2.27
1959-1960	0.48		30.9	25.9	6.18	2.27
1961	0.48		34.2	29.5	6.30	2.47
1962	0.48		27.2	21.8	6.04	2.04
1963	0.47		13.9	7.0	5.56	1.23
1964	0.46		10.7	3.5	5.45	1.03
1965	0.46		10.2	3.0	5.43	1.00
1966[a]	0.23	0.072	4.8	2.4[b]	2.71	0.97[b]

[a] Doses prorated to first 6 months, except as noted

[b] Doses should be prorated to first 6 months

BOUNDING INTERNAL EXPOSURES: Apply to All Employees

Lognormal Distribution Parameters of Surrogate Data Set*

Parameter	(dpm/m^3)
Geometric mean	17.54
Arithmetic mean	24.72
95th %ile	68.70

* Agreed upon by W-G, SC&A, & NIOSH

Intakes by All Workers

Start date	End date	Inhalation (dpm/cal. day)	
		SC&A	NIOSH
1/1/1953	6/30/1961	264.16	29.81
7/1/1961	6/30/1962		34.37
7/1/1962	6/30/1963		20.12
7/1/1963	6/30/1965		15.69
7/1/1965	6/30/1966		15.01
After 6/30/1966*			1.44

*Exponentially decreasing

Basis for Disagreement Between SC&A and NIOSH: Inhaled Intakes of Uranium

- NIOSH Model
  - Exposure to 68.7 dpm/m^3 during 20% of uranium handling hours each year
  - One-time deposition for 30 d—based on TBD-6000
  - Constant surficial contamination: 1.34×10^5 dpm/m^2
  - RF = 10^{-5} m^{-1}

- 30-d deposition not applicable to intermittent uranium air concentrations
  - Requires 1,944-m-high column of contaminated air
  - Effective RF = $\frac{X}{S} = \frac{68.7 \frac{dpm}{m^3}}{1.34 \times 10^5 \frac{dpm}{m^2}} \approx 5 \times 10^{-4}\ m^{-1}$
  - Workers would be exposed to inhalation of uranium aerosols being deposited, but not accounted for in model

- Inconsistent assumptions:
  - Deposition based on air concentration of 68.7 dpm/m^3
  - Inhalation (except during uranium operations) based on air concentration of 1.34 dpm/m^3

- Control room not airtight—betatron operators would be exposed to uranium dust during radiographic exposures

- SC&A model
    - Bounding assumptions
        - All workers exposed to uranium dust
        - Concentration based on full lognormal distribution
    - Exponentially decreasing during residual period, according to OTIB-70