Review of NIOSH Response Paper: July 10, 2015

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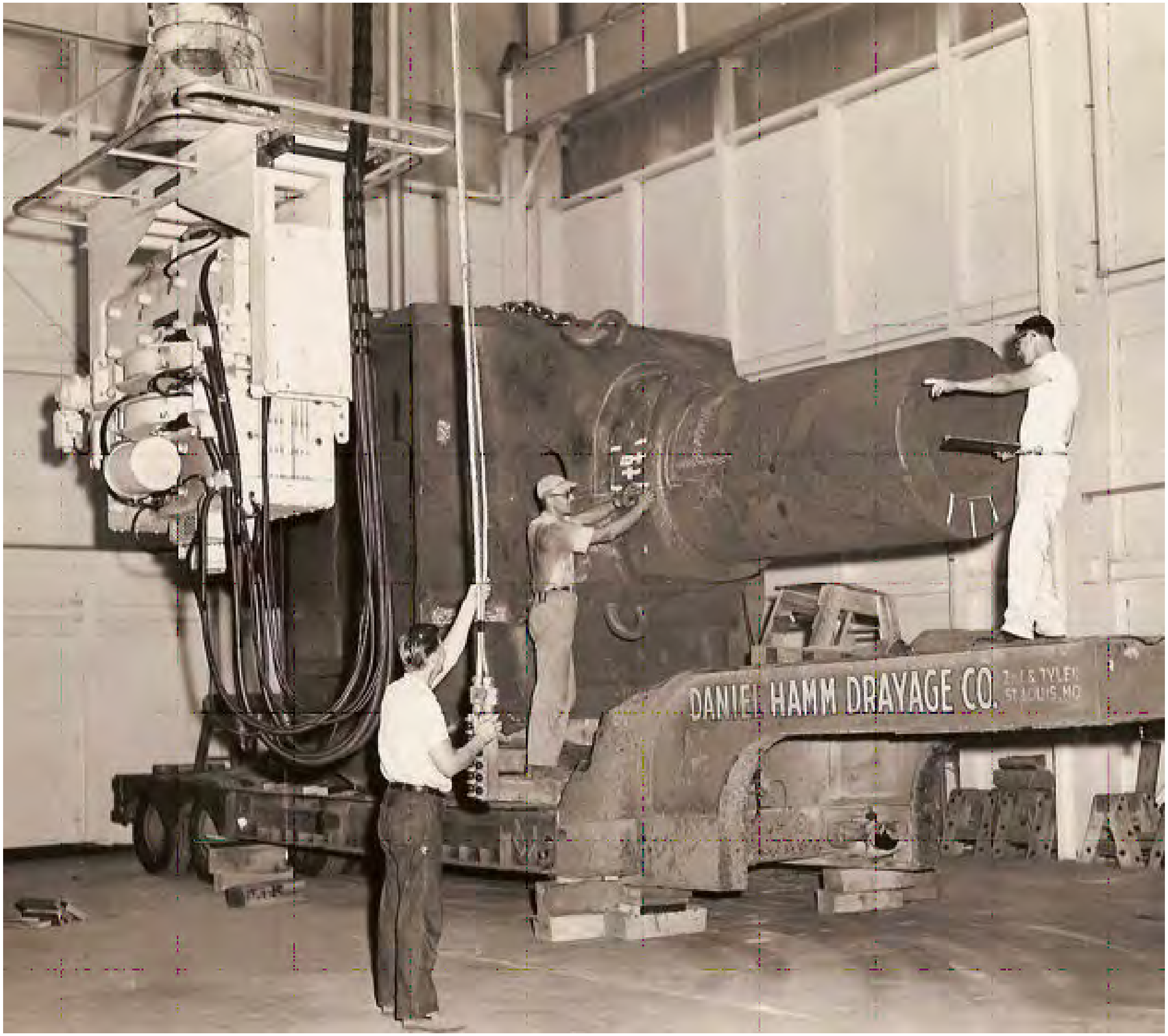
Finding 2: Betatron Operator Beta Doses

- Skin doses from uranium
  - New SC&A analysis used intermittent exposure model developed by NIOSH for irradiated steel
  - NIOSH calculations based on continuous irradiation of uranium
  - SC&A created more realistic MCNPX model of uranium disk to simulate photoactivation
- Skin doses from irradiated steel
  - SC&A verified NIOSH model
  - SC&A estimates 0–1% lower due to different calculations of betatron beam intensity
- NIOSH skin dose estimates bounding and claimant favorable
  - NIOSH may wish to adopt lower, more realistic skin doses from uranium

Finding 10: Betatron Operator Gamma Dose

- NIOSH response:
  - Betatron operator photon exposure scenario only used for doses to the skin of the hands and forearms—confirmed by SC&A
  - Hands and forearms exposed to betatron only ½ time, remainder of time shielded by body
- SC&A reply:
  - Photograph shows betatron operator holding his left hand and forearm above his shoulders and his right arm at the side of his body
  - NIOSH should assume hands and forearms exposed to betatron full time
  - Recommended skin dose to hands/forearms: 10.225 rad (air kerma) × 0.654 rem/rad = 6.687 rem/y



Betatron Radiography of the Axle of a Power Shovel Cast at GSI

Finding 5: Adding Betatron Operator Dose to Radium Radiography Dose

- NIOSH response:
  - Setup time: 15 minutes between shots—15 min/shot × 10 shots/shift = 150 min/shift = 2.5 h/shift
  - Radiographic exposures: 30% × 8 h = 2.4 h/shift
  - Maximum time left for work in betatron: 8 h − 2.5 h − 2.4 h = 3.1 h ÷ 8 h = 38.75%
  - Assumption that same radiographer performed all uranium radiography represents unjustified bias

- SC&A Reply:
  - Radium Era worker said he spent 50%–60% of each radiography shift in betatron building
  - Worker's film dosimetry records consistent with the agreed-upon estimates of external exposures
  - Upper end of range: 60% = plausible upper bound of time in betatron building
  - Time between shots:
    - Radiographer took 12–15 s to transport radium source from lead pig and position it for the exposure
    - Film was most likely stored nearby (in radiographer's office inside facility in #6 Building)
    - Films developed in batches during long shots
      - Average shot: 2.4 h ÷ 10 = 0.24 h ≈ 14 min
      - Range: 1–70 min (reported by GSI official to AEC inspector)
    - Casting larger than 1 film, required several shots—no need to replace casting after every shot
  - One worker could perform radium radiography and all betatron radiography of uranium, resulting in higher skin and neutron doses
    - Maximum time on uranium radiography = 437.5 h/y ≈ 13.5% of all shifts

Finding 6: Layout Man Beta Dose

- NIOSH response:
  - All castings irradiated intermittently (setup—expose—setup—expose, etc.)
  - Layout man spent most of shift on one casting (single casting scenario)
  - Often spent 15 min on freshly irradiated casting—total 10% of shift (interrupting casting scenario)
  - Same amount of time on each casting, whether long or short shot
  - 90% of time on short shots—10% on long shots

- SC&A reply: accept NIOSH model as bounding and claimant favorable, except for time on long vs. short shots
  - Long shots took longer to mark up: steel much thicker, therefore had more defects
    - Account of GSI worker at last W-G meeting:
      - The bigger the casting . . . [the] more defects
      - Missile tubes for Polaris submarine had fewer defects
    - Polaris missile tubes <5-in thick (Cdr. John Harrop, USN [ret], former engineering officer on Polaris submarines)
    - Cavity . . . defect is partly a function of section thickness designed into casting (American Foundry Society)
    - The larger and more complex the casting, the [more likely the] . . . defects (William C. Thurber, metallurgist)
  - SC&A recommendation:
    - Maximum ratio of time per casting long:short = 5:1 based on time in betatron (75 min:15 min)
    - Minimum ratio 1:1
    - Average ratio 3:1—for *n* long shots and 9*n* short shots, fraction of time on long shots = $\frac{3n}{3n + 9n} = 0.25\%$

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

Skin on:	Dose (rad/y)				
	SC&A-1[a]	SC&A-2[b]	NIOSH-1[c]	NIOSH-2[d]	New[e]
Hands and forearms	1.89	0.278	0.807	0.264	0.405
Rest of body	1.14	0.178	0.463	0.147	0.224

[a] SC&A review of Appendix BB, Rev. 1 (2014)

[b] Same scenario as SC&A-1 but recalculated using intermittent exposure algorithm

[c] Appendix BB, Rev. 1 (2014)

[d] NIOSH (July 10, 2015)

[e] Same scenario as NIOSH-2, recalculated by SC&A assuming 25% of time spent marking up long shots

- Minor contribution vs. 9 R/y photon exposure

ISSUE RESOLUTION MATRIX FOR SC&A FINDINGS ON APPENDIX BB, REV. 1

- Issue 1 (neutron dose rates): NIOSH agreed to resolve this issue.
- Issue 2 (beta dose to skin of betatron operator): SC&A agrees that NIOSH estimates are bounding.
- Issue 3 (no dedicated radiographic facility in No. 6 Building prior to 1955): NIOSH agreed to resolve this issue.
- Issue 4 (maximum of triangular distribution of photon exposures for 1961 should be 12 R/y): NIOSH agreed to resolve this issue.
- Issue 5 (combined exposures to ^{226}Ra and betatron operations during 1952–1962): In progress, pending resolution of differences between DCAS and SC&A.
- Issue 6 (beta skin dose to layout man): In progress, pending resolution of differences between DCAS and SC&A.
- Issue 7 (uranium inhalation from metal handling in 1966): NIOSH agreed to resolve this issue.
- Issue 8 (ingestion intakes not consistent with OCAS-TIB-009): NIOSH agreed to resolve this issue.
- Issue 9 (ingestion intakes during residual period): NIOSH agreed to resolve this issue.
- Issue 10 (external exposure of betatron operator): In progress, pending resolution of differences between DCAS and SC&A.

POTENTIAL IMPACTS ON PAST AND FUTURE CLAIMS

- Issue 1 (neutron dose rates): neutron doses higher
- Issue 2 (beta dose to skin of betatron operator): beta skin doses lower
- Issue 3 (no dedicated radiographic facility in No. 6 Building prior to 1955): photon doses higher 1952–55
- Issue 4 (maximum of triangular distribution of photon exposures for 1961 should be 12 R/y): photon doses lower in 1961
- Issue 5 (combined exposures to ^{226}Ra and betatron operations during 1952–1962): neutron and beta skin doses higher during 1952–1962
- Issue 6 (beta skin dose to layout man): beta skin doses lower
- Issue 7 (uranium inhalation from metal handling in 1966): intake doubled during first 6 months of 1966
- Issue 8 (ingestion intakes not consistent with OCAS-TIB-009): ingestion rates lower during operational period
- Issue 9 (ingestion intakes during residual period): ingestion rates lower during residual period
- Issue 10 (external exposure of betatron operator): doses to skin of hands and forearms higher